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The Control of Nitrate as a Water Pollutant

Texas Agricultural Experiment Station, College Station

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This study was based on the premise that the most logical approach to reducing nitrate leaching in soils was to limit the amount of nitrate in the soil solution at any one time. Methods of limiting the concentration of nitrate in the soil solution while maintaining an adequate supply of available nitrogen for plant growth are reported.

Timing of nitrogen application was found to be a very effective means of reducing nitrate leaching. When nitrogen was applied in the fall as much as 3-fold more nitrate was found to have leached below 60 cm in the soil by June as compared to applications made in March. A nitrification inhibitor, N-Serve, was found to be very effective in reducing the amount of nitrate leached. Slow release sulfur-coated ureas and treatment of nitrogen fertilizers with N-Serve were found to be effective means of reducing leaching losses of nitrate when fertilizers were applied in the fall or winter.

Losses of 0.5 and 3.6% of nitrogen applied as fertilizer occurred in runoff water when normal rates of nitrogen were applied to a grassland watershed. Lysimeter studies indicated that from 0.04% to 6% of the applied fertilizer nitrogen could be leached below 120 cm in a silt loam soil depending on the source of nitrogen.

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THE CONTROL OF NITRATE AS A WATER POLLUTANT

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C. Galegar
Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

This study was based on the premise that the most logical approach to reducing nitrate leaching in soils was to limit the amount of nitrate in the soil solution at any one time. Methods of limiting the concentration of nitrate in the soil solution while maintaining an adequate supply of available nitrogen for plant growth are reported.

Timing of nitrogen application was found to be a very effective means of reducing nitrate leaching. When nitrogen was applied in the fall as much as 3-fold more nitrate was found to have leached below 60 cm in the soil by June as compared to applications made in March. A nitrification inhibitor, N-Serve, was found to be very effective in reducing the amount of nitrate leached. Slow release sulfur coated ureas and treatment of nitrogen fertilizers with N-Serve were found to be effective means of reducing leaching losses of nitrate when fertilizers were applied in the fall or winter.

Losses of 0.5 and 3.6% of nitrogen applied as fertilizer occurred in runoff waters when normal rates of nitrogen were applied to a grassland watershed. Lysimeter studies indicated that from 0.04 to 6% of the applied fertilizer nitrogen could be leached below 120 cm in a silt loam soil depending on the source of nitrogen.

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SECTION 1

INTRODUCTION

Nitrate occurrence in ground water aquifers in Texas is widespread (George and Hastings, 1951). George and Hastings (1951) surveyed 20,000 wells in 101 Texas counties and found that 15% or 3,000 of the wells contained over 4.5 ppm NO_3-N. Runnels County, in the west central part of the state, is well known for its high nitrate containing groundwaters. Jones (1973) investigated the unusually high concentrations of nitrates in the groundwaters in Runnels county and concluded that most of the groundwater contamination was caused from natural nitrates in the area and was not caused by the activities of man.

In 1969, 38 domestic water wells in Central Texas were analyzed for nitrates (Swoboda, 1969). Eleven of these wells were found to contain over 10 ppm NO_3-N which is the maximum level established by the U. S. Public Health Service (1962) for drinking water. The NO_3-N concentrations of the 38 wells tested ranged up to 332 ppm. All eleven wells which were found to contain excessive nitrate levels were located under heavy montmorillonitic clay soils. Thomas and Swoboda (1967) and Kissel et al. (1973) reported that anions such as nitrate can be readily leached in montmorillonitic soils under proper moisture conditions.

This study was undertaken to:
A. Quantitate the amount of nitrate lost from the soil under various controlled environmental conditions.
B. Develop practical farming methods which reduce the amount of nitrate which is lost from the soil by leaching and runoff.
C. Develop certain guidelines for the optimum use of nitrogen fertilizers while limiting the amount of nitrate entering our natural resources.

Since it is well documented that nitrates can readily move through soils which do not have a significant anion adsorptive capacity, the basic premise of this study was to devise methods of maintaining fertilizer nitrogen in the NH_4 form as long as possible. The NH_4 form of nitrogen can be adsorbed by the negatively charged sites on the clay and restrict its movement through the soil. Three basic methods of maintaining the applied fertilizer nitrogen in the NH_4 form were investigated. The first method investigated was microbial immobilization and release. This technique provides a natural slow release source of nitrogen which would limit the amount of NO_3 present in the soil at any one time. The second technique investigated was the inhibition of the nitrification process in soils by treatment of fertilizer with a specific microbicide. This method would delay the conversion of NH_4

to NO_3. The third method was the use of slow release or slowly soluble nitrogen source which should limit the amount of NH_4 and NO_3^- which is present in the soil at any time. Also investigated was the timing of applications of various nitrogen sources prior to planting on the movement of NO_3 through the soil.

To determine the effect excessive rainfall has on the loss of fertilizer nitrogen in runoff waters, a grassland watershed was fertilized and the runoff water monitored for NO_3. Movement of NO_3 into shallow groundwater aquifers in the watershed was also investigated.

Nitrate movement through a soil was quantitated by using 5 lysimeters to collect percolating soil water. The lysimeters were fertilized with 3 different sources of nitrogen and the percolating water was collected throughout the year and analyzed for NH_4 and NO_3.

SECTION 2

RECOMMENDATIONS

The two most important factors to consider in relation to limiting the loss of fertilizer nitrogen by leaching are the rate of application and the time of application. Nitrogen should not be applied at rates exceeding economic plant response. This is normally no more than what the plant can take up from the soil in a 2-3 week period. The nitrogen should be applied as near to the time of plant use as possible.

If it is necessary to apply more nitrogen than what the plant can take up in a 2-3 week period it is advisable to apply the nitrogen at different times. This is especially true for small grains and improved pastures.

Leaching losses are directly related to the amount of rainfall which occurs. It is advisable not to apply high rates of nitrogen just prior to an expected rainy period. Nitrogen should not be surface applied prior to a high rainfall season. This can result in nitrogen being lost in runoff water as well as leaching waters.

Nitrogen should not be applied between October and February whenever possible. When fall or winter applications are necessary, a nitrification inhibitor such as N-serve will reduce the amount of nitrogen being leached as NO_3. Slow release nitrogen sources such as sulfur coated urea are also recommended when fall or winter applications are necessary. Whenever possible an ammonium or urea source of nitrogen should be used rather than a nitrate source. This is especially true for fall or winter applications. Ammonium is not nearly as subject to leaching losses as nitrate.

SECTION 3

CONCLUSIONS

1. The addition of a carbon source with fertilizer nitrogen was effective in reducing the concentration of NO_3 in the soil solution by microbial immobilization. However, the recovery of applied nitrogen by plants was not increased and the amount of nitrogen lost by leaching was not appreciably reduced.

2. A nitrification inhibitor, N-Serve, was found to be very effective in reducing the amount of NO_3-N lost from leaching columns treated with ammonium and the inhibitor. Forage yields of oats were increased slightly by the addition of the inhibitor and the concentration of NO_3 in the plant tissue was reduced considerably.

3. In field studies, time of nitrogen application had a significant effect on the amount of nitrate leaching in the soil. Generally 10-30% more nitrogen was found in soil profiles during the growing season when the fertilizer was applied at the time of planting as compared to fall or winter applications. In addition, 2-3 times more nitrogen had leached below 60 cm by June from the fall application as compared to applications at the time of planting.

4. Slow release sulfur coated ureas (SCU) were effective sources for reducing the amount of nitrate leaching. Although more nitrogen remained in the upper part of the soil profile during the growing season with the use of SCU, the yield of grain sorghum was not increased.

5. The nitrification inhibitor, N-Serve, was effective in maintaining fall and winter applied nitrogen in the NH_4 form for a substantial period of time. Addition of N-Serve to the N source resulted in up to 30% less NO_3 leaching.

6. Runoff losses of nitrogen from fertilizer applied to a grassland watershed were insignificant. In 1974, 0.5% of the applied nitrogen was detected in the runoff water and 3.6% of the 180 kg/ha applied in 1975 was detected in the runoff water.

7. Concentrations of NO_3 in shallow wells located in the watershed fertilized twice each year with 90 kg/ha of nitrogen were appreciable following the initial rains following fertilization. Concentrations as high as 61 ppm NO_3-N were detected in the well waters.

8. Lysimeter studies indicated that even though NO_3-N concentrations as high as 32 ppm were present in the effluent below 120 cm of soil the total amount of nitrogen lost by leaching was low. Concentrations of NO_3-N generally ranged from 0-3 ppm in the effluent from the lysimeters. The greatest leaching losses (6%) occurred when $Ca(NO_3)_2$ was applied to the soil. Leaching losses from the application of 168 kg-N/ha as NH_4Cl or SCU-20 ranged from 0.04 to 2.1% over a two year period.

SECTION 4

MICROBIAL IMMOBILIZATION AND RELEASE

LABORATORY INCUBATION

Soil microbes require nitrogen in their metabolic processes. The nitrogen utilized by these microbes will be immobilized and not available to plants or be free to leach through the soil. As the microbes slowly die and their bodies decompose, the nitrogen again becomes available to plants. This temporary immobilization of nitrogen by microbes provides a possible slow release source of nitrogen which would reduce the chances of it being leached through the soil. Incorporating a carbon source with fertilizer nitrogen should stimulate the microbial population in the soil and immobilize a considerable amount of applied nitrogen. By proper timing of fertilization with nitrogen mixed with a carbon source, nitrogen could become available to growing plants at a rate sufficient to maintain maximum yeilds.

Procedure

One kilogram of Norwood silt loam soil was added to two liter plastic containers. Nitrogen as $Ca(NO_3)_2$ and sucrose were thoroughly mixed with each soil as indicated in Table 1. Duplicates of each treatment were incubated at 19°C for 71 days at near field capacity. Soil samples of approximately 20 gms were taken from each container every 2 to 3 days with a cylindrical probe. The moist samples were extracted immediately with 0.2 $\underline{N}$ K_2SO_4 or were frozen until they could be extracted. Nitrates were determined in the extract by the phenoldisulfonic acid method and ammonium by steam distillation.

Results

The microbial population in the soil which was stimulated by the addition of carbon and nitrogen did reduce the amount of soluble nitrate in the soil. Figure 1 shows the amount of nitrate nitrogen in the soil when no nitrogen or carbon was added (ck), and when 100 ppm of nitrogen as $Ca(NO_3)_2$ was added (0:1). The amount of nitrate in solution at any time was much greater when nitrogen was added than in the check treatment. The NO_3-N concentration in the check sample ranged from 9 to 25 ppm. In the sample receiving 100 ppm N, the NO_3-N concentration ranged from 38 ppm to 139 ppm.

The addition of carbon, as sucrose, reduced the soluble nitrate concentration considerably, especially at the high rates of carbon (Fig. 2). The addition of 500 ppm carbon (5:1) reduced the NO_3-N concentration to 60 ppm after 2 days. The NO_3-N increased to 102 ppm after 8 days and decreased

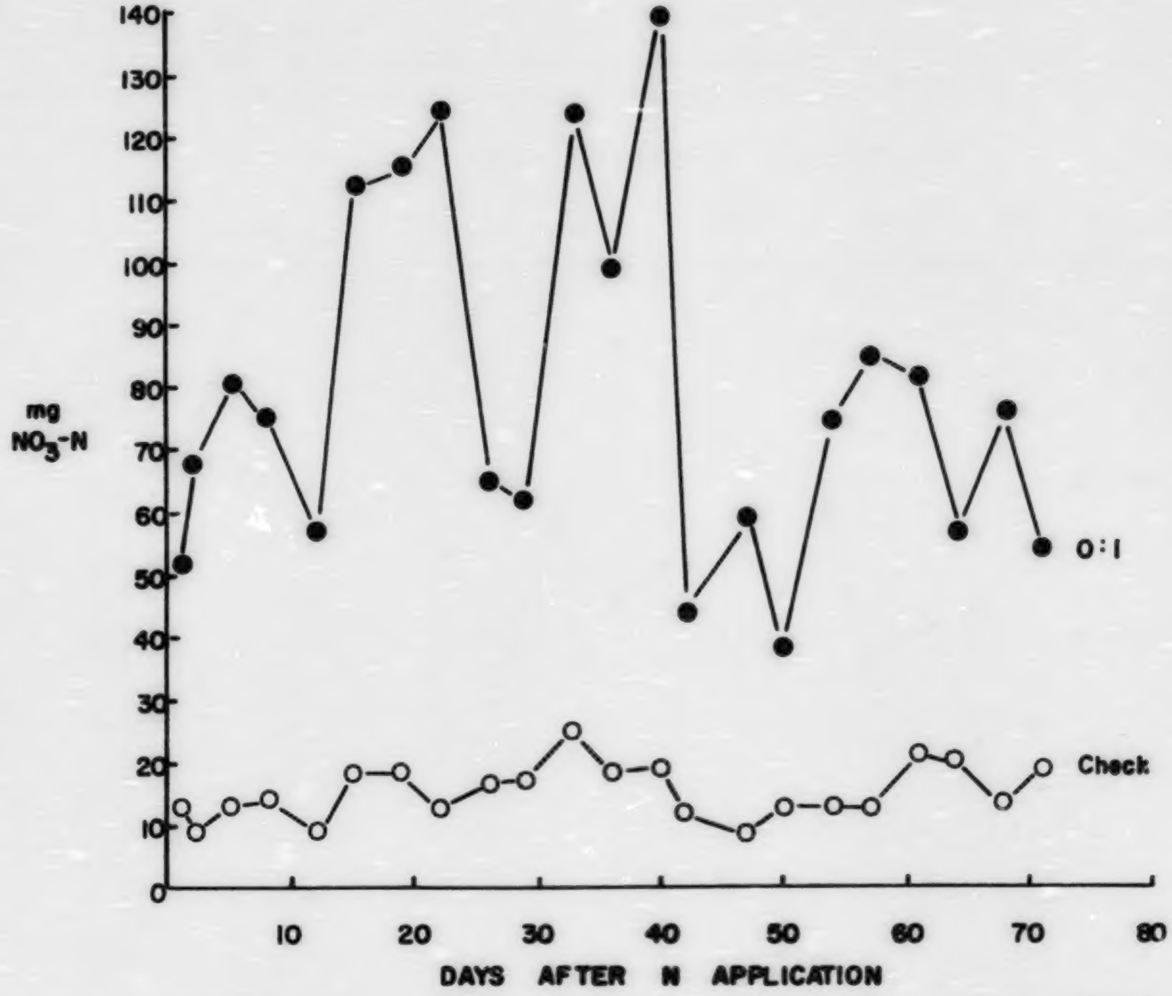

Figure 1. Nitrate-N concentration in Norwood silt loam soil incubated at 19°C for 71 days with or without addition of $Ca(NO_3)_2$.

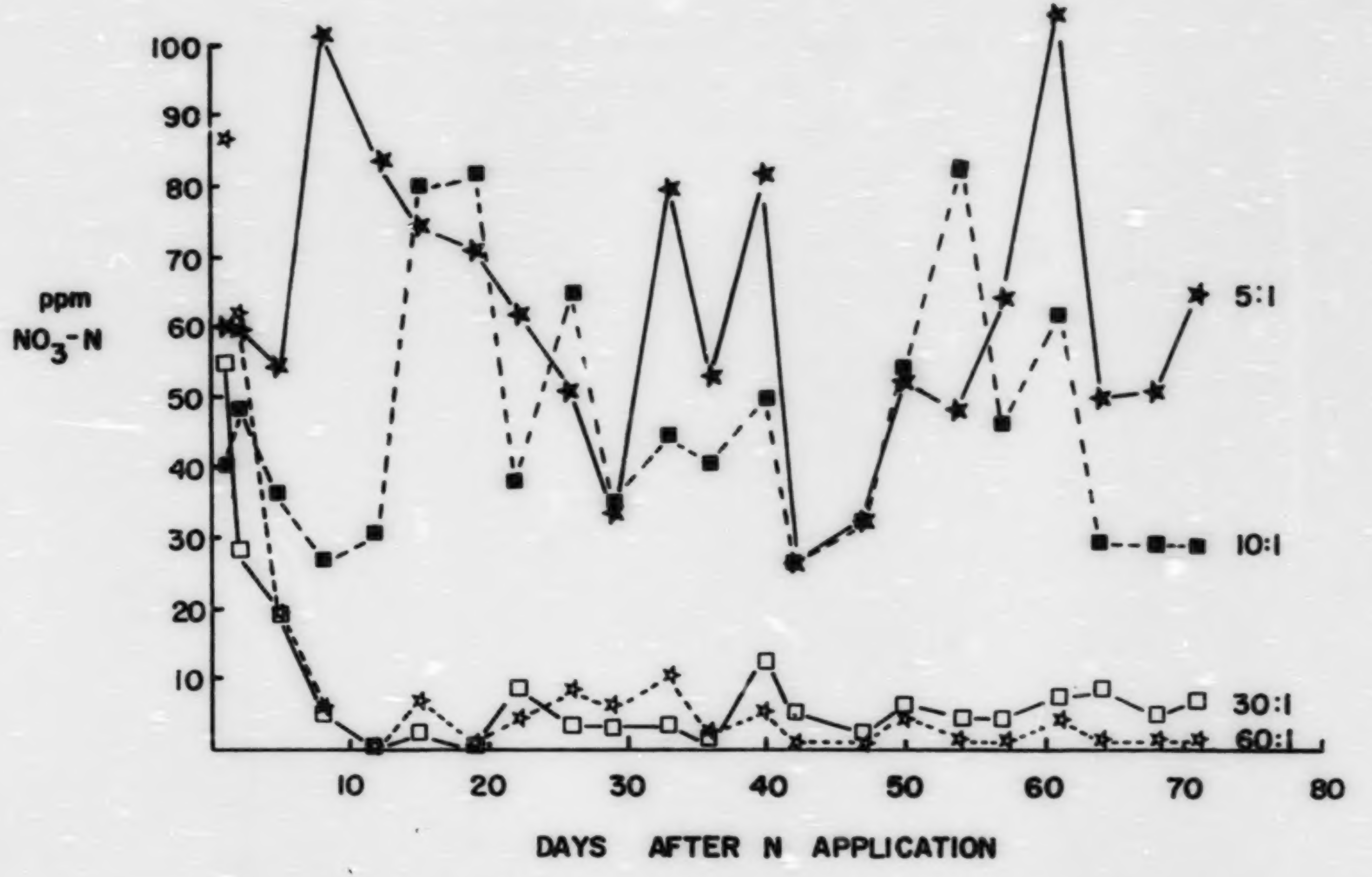

Figure 2. Nitrate-N concentration in Norwood silt loam soil incubated at 19°C for 71 days after adding various amounts of carbon, as sucrose, and 100 ppm N as $Ca(NO_3)_2$.

TABLE 1. RATES OF NITROGEN AND CARBON ADDED TO 1000 G. NORWOOD SILT LOAM IN IMMOBILIZATION STUDY

Treatment No.	Carbon* (gms.)	Nitrogen* (gms.)	C:N Ratio
1	0	0	----
2	0	0.1	----
3	0.5	0.1	5:1
4	1.0	0.1	10:1
5	3.0	0.1	30:1
6	6.0	0.1	60:1
7	0.5	0	----
8	1.0	0.0	----
9	3.0	0.0	----
10	6.0	0.0	----

* Carbon added as sucrose and nitrogen added as $Ca(NO_3)_2$.

continually until it reached 35 ppm after 29 days of incubation and again increased sharply. There appeared to be three cycles of high concentrations followed by low concentrations. The same trend seemed to occur when the carbon:nitrogen ratio of the soil amendment was increased to 10:1, although the concentrations were slightly lower. When the ratio was increased to 30:1 or 60:1, the NO_3-N concentration decreased from 55-86 ppm after 1 day to less than 10 ppm after 8 days. The concentration remained below 10 ppm for the remainder of the 71 days of incubation except for one sampling date in which the concentration reached 12 ppm.

The addition of a carbon source with nitrogen fertilizers did reduce the amount of nitrate in the soil solution. The availability of this nitrogen to plants under leaching conditions was investigated under greenhouse conditions.

PLANT UPTAKE AND LEACHING LOSSES FROM MICROBIAL IMMOBILIZED NITROGEN

The objective of this experiment was to determine if microbial immobilization of nitrogen could be utilized as an effective means of reducing the leaching of nitrates while maintaining optimum yields.

Procedure

Lakeland sand was placed in 15 cm diameter polyvinyl chloride (PVC) columns to a depth of 27.5 cm. The columns had sealed bottoms with a drain for effluent collection. The columns were leached with sufficient distilled water until no nitrate was present in the effluent. Nitrogen and carbon were surface applied on May 11, 1973, at the rates indicated in Table 2. There were 3 replications for each treatment. Nitrogen was applied as $Ca(NO_3)_2$ at a rate equivalent to 224 kg-N/ha. Carbon was supplied as either sucrose or motor oil. The sucrose analyzed 37.6% carbon and the oil 83.4% carbon. After the carbon sucrose and nitrogen were applied, they were covered with an additional 2.5 cm of soil to give a total depth of 30 cm.

TABLE 2. AMOUNT OF NITROGEN AND CARBON AS SUCROSE OR OIL, APPLIED TO LAKELAND SAND COLUMNS PLANTED IN SUDAN GRASS

Treatment No.	Carbon Source	Carbon (gms.)	Nitrogen (gms.)	C/N Ratio
1	--	0.0	0.0	--
2	--	0.0	0.41	--
3	sucrose	2.05	0.41	5:1
4	sucrose	5.10	0.41	10:1
5	sucrose	12.30	0.41	30:1
6	sucrose	24.60	0.41	60:1
7	oil	2.05	0.41	5:1
8	oil	4.10	0.41	10:1
9	oil	12.30	0.41	30:1
10	oil	24.60	0.41	60:1

The pots were allowed to incubate 14 days in a greenhouse maintained between 20° and 30°C. On May 24, 1973, sweet sudan grass (Sorghum vulgare sudanenese) was planted at the rate of 40 seeds per column. Potassium, phosphorus, and zinc were applied to each pot at rates equivalent to 224, 112, and 2.2 kg/ha, respectively, on June 4, 1973. The sudan was replanted on June 11, 1973, due to poor germination at the high rates of applied carbon.

Water was applied at the rate of 5 to 7 cm per week as required to obtain leaching. Leachate was analyzed for nitrate and ammonium after total volume of leachate was recorded.

Forage yields were harvested on July 2, August 14, October 1, and November 7, 1973. Phosphorous, equivalent to 112 kg/ha, was applied on July 25, 1973, and on August 3, 1973, K, P, and Zn were again applied to each pot at the same rates as the initial application. To correct a nitrogen deficiency evidenced in the second cropping, nitrogen was again applied on September 5, 1973, to the nitrogen treated pots at a rate equivalent to 224 kg-N/ha as $Ca(NO_3)_2$. Following the final forage harvest, soil samples were taken from each pot and root weights were obtained. Root yields were obtained by removing the entire soil and placing it on a screen table and washing the soil from the roots. The forage and roots were dried at 55°C. Total nitrogen was determined in the forage and root tissue by Kjeldahl digestion and distillation.

Results

The high rates of sugar and oil restricted germination after the 14 day incubation period. Seedlings were removed from all treatments and sorghum replanted 32 days after applying carbon and nitrogen.

The cumulative losses of nitrate-N in the drainage effluents are shown in Figures 3 and 4. The addition of carbon with the nitrogen fertilizer did tend to reduce the amount of nitrates lost in the leaching during the first 60 days. Whereas, when sucrose was added to give C/N ratios of 5:1 and 10:1, the amount of nitrogen lost, respectively, was only 65 and 93% as much as when no sucrose was added. More nitrates were lost at the 30:1 C/N ratio than when no carbon was added. This could be caused by a high osmotic pressure of the solution caused by the addition of sucrose which limited the buildup of a suitable microbial population. More nitrates appear to have been lost at the 30:1 C/N ratio than when no carbon was added. The high loss shown in Figure 3 is the result of one replication having an extremely high effluent concentration. The other two replications of the 30:1 treatment had leaching losses similar to the 60:1 treatment.

Forty-one grams of nitrogen were reapplied to the pots 96 days after the initial application. The nitrate in the effluent increased sharply. However, the amount lost from the 30:1 treatment was much less than from the treatment receiving no sucrose. The reduction in nitrate loss over the 117 day growing period by the addition of sucrose was 22, 5, 7, and 21% by the 5:1, 10:1, 30:1, and 60:1 treatments, respectively.

The addition of oil as a carbon source appeared to decrease nitrate leaching similar to sucrose. After the initial application of nitrogen and carbon, the low C/N ratio applications caused less loss of N than the higher ratios (Fig. 4).

Nitrate losses were reduced 6.5% by the C/N treatments of 5:1 and 10:1. The 30:1 and 60:1 treatments both increased the amount of N loss over the treatment receiving no carbon. After the second addition of nitrogen, all carbon treatments reduced nitrate leaching. It appears that the detrimental effect of the high rates of oil on the microbial population has been overcome after being in the soil for 96 days prior to the second application of nitrogen. The reduction in nitrate leaching caused by the addition of oil and two nitrogen applications was 50, 19, 26, and 9% for the 5:1, 10:1, 30:1, and 60:1 treatments, respectively.

The addition of carbon did not affect forage yields of the sudan grass except at the higher levels of added carbon. The addition of carbon to give a C/N ratio of 5:1 appears to increase yields of the first harvest (Table 3) for both the sucrose and oil treatments. The first forage harvest indicated that the carbon treatments at the C/N ratios of 30:1 and 60:1 had a detrimental effect on plant growth. However, the second, third, and fourth harvestsdid not indicate a reduction in yield due to the large addition of carbon. The total yields of the four harvests were not reduced by the addition of sucrose or oil except at the 60:1 level.

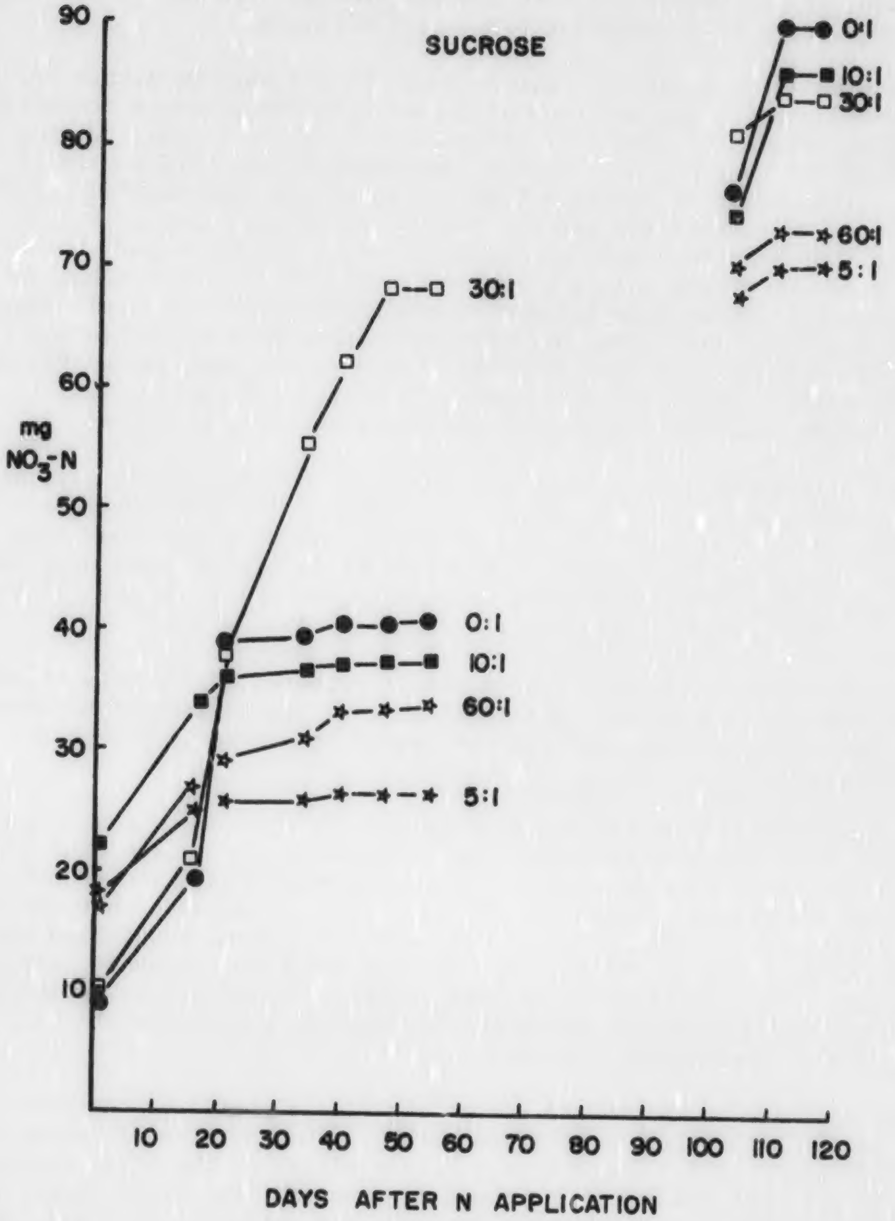

Figure 3. Accumulative loss of NO_3-N in effluent from Lakeland sand columns treated with different ratios of carbon:nitrogen as sucrose and $Ca(NO_3)_2$.

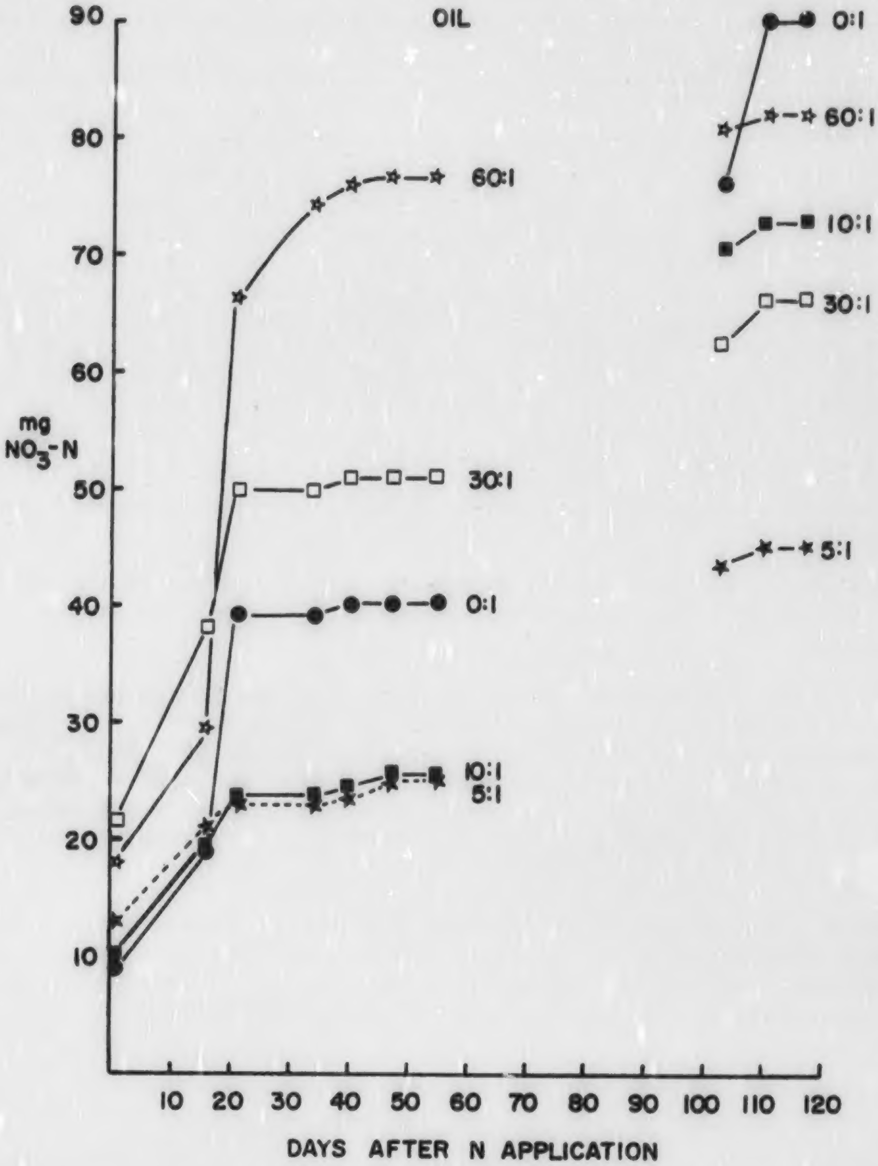

Figure 4. Accumulative loss of NO_3-N in effluent from Lakeland sand columns treated with different ratios of carbon: nitrogen as oil and $Ca(NO_3)_2$.

TABLE 3. YIELD OF FORAGE FROM FOUR HARVESTS OF SUDAN GRASS GROWN ON LAKELAND SAND AND TREATED WITH SUCROSE, OIL, AND $Ca(NO_3)_2$.

Treatment				Harvest				
N	C	Source	C/N	1st	2nd	3rd	4th	Total
0.0	0.0	--	--	0.90	2.10	1.08	.47	4.6
0.41	0.0	--	--	14.8	5.3	21.4	2.8	44.3
0.41	2.05	sucrose	5:1	17.8	5.6	19.3	2.6	45.3
0.41	4.10	sucrose	10:1	15.9	5.5	18.4	2.5	42.3
0.41	12.30	sucrose	30:1	8.5	7.4	28.0	4.1	48.0
0.41	24.60	sucrose	60:1	2.6	11.9	21.6	2.6	38.7
0.41	2.5	oil	5:1	16.9	5.0	19.2	2.8	43.9
0.41	4.10	oil	10:1	14.8	4.8	19.6	2.6	41.8
0.41	12.30	oil	30:1	14.4	4.8	21.2	3.3	43.7
0.41	24.60	oil	60:1	8.3	6.1	19.9	.46	34.8

The uptake of nitrogen by the plants was not increased by the addition of carbon (Table 4). The oil treatments actually reduced the amount of nitrogen taken up.

Although the addition of carbon did not stimulate forage production, it did increase the amount of roots produced. The higher rates of carbon, generally, produced more roots than the lower rates (Table 5). The yield of roots was increased by 198% in the case of the 60:1 sucrose treatment. The roots of the plants receiving the higher carbon treatments appeared to contain more of the total nitrogen taken up, even though they had a lower nitrogen content.

Microbial immobilization of nitrogen did tend to decrease the amount of NO_3 movement through soils, although it did not increase plant response or nitrogen uptake. It does not appear that this technique would be very practical for reducing the amount of nitrate leaching in soils.

TABLE 4. NITROGEN UPTAKE BY FOUR HARVESTS OF SUDAN GRASS GROWN ON LAKELAND SAND TREATED WITH SUCROSE, OIL, AND $Ca(NO_3)_2$.

Treatment				Harvest				
N	C	Source	C/N	1st	2nd	3rd	4th	Total
gms				mg N				
0.0	0.0	--	--	14	12	14	4	44
0.41	0.0	--		216	28	167	25	436
0.41	2.05	sucrose	5:1	261	32	108	23	424
0.41	4.10	sucrose	10:1	213	30	153	24	420
0.41	12.30	sucrose	30:1	106	33	170	30	339
0.41	24.60	sucrose	60:1	50	55	195	24	324
0.41	2.05	oil	5:1	178	26	147	23	374
0.41	4.10	oil	10:1	168	24	143	24	359
0.41	12.30	oil	30:1	158	28	156	29	371
0.41	24.60	oil	60:1	111	29	114	23	277

TABLE 5. YIELD AND NITROGEN CONTENT OF SUDAN GRASS ROOTS GROWN IN POTS OF LAKELAND SAND TREATED WITH SUCROSE, OIL, AND $Ca(NO_3)_2$.

Treatment				Yield	Nitrogen	
N	C	Source	C/N	gms.	mg.	%
0.0	0.0	--	--	4.7	26.4	.56
0.41	0.0	--	--	32.8	165.6	.50
0.41	2.05	sucrose	5:1	34.6	197.3	.57
0.41	4.10	sucrose	10:1	43.6	250.1	.57
0.41	12.30	sucrose	30:1	45.4	179.3	.39
0.41	12.30	sucrose	30:1	45.4	179.3	.39
0.41	24.60	sucrose	60:1	65.0	314.1	.48
0.41	2.05	oil	5:1	40.5	214.8	.53
0.41	4.10	oil	10:1	33.5	185.6	.55
0.41	12.30	oil	30:1	32:3	189.9	.59

SECTION 5

NITRIFICATION INHIBITORS

Nitrate is the water soluble form of nitrogen most prevalent in soils and is subject to leaching. Ammonium, which is also very prevalent in soils, is seldom leached in soils due to its cationic nature, but is readily taken-up by plants. However, ammonium is readily nitrified in agricultural soils to nitrate which can be lost by leaching. Nitrification inhibitors, which would limit or prevent the conversion of ammonium to nitrate, should be very effective in preventing leaching losses of nitrates.

This study was undertaken to determine if N-Serve, 2-chloro-6(trichloromethyl)-pyridine, a nitrification inhibitor produced by the Dow Chemical Company, would be effective in restricting the nitrification of ammonium and thereby limiting the movement of nitrogen in soils under greenhouse and field conditions.

PROCEDURE

Soil columns 25 cm in diameter and 45 cm in depth were used. Each column contained 22 kg of Norwood silty clay loam soil. Drainage outlets were placed in the bottom of each column for collection of effluent samples.

Treatments were applied in triplicate as shown in Table 6. The check received no nitrogen or N-Serve while the calcium nitrate and ammonium sulfate treatments were applied at the rate of 400 kg-N/ha in a band 5 cm below the soil surface and oats (Avena sativa) were planted in two rows, one on each side of the fertilizer band on February 8, 1973. Twenty-five seeds were planted in each row. A total of 1.96 g N was applied to each column. Calcium sulfate was applied with the calcium nitrate to equal the amount of sulfate added in the ammonium sulfate. N-Serve was applied as a percentage of total nitrogen applied, and mixed with the ammonium sulfate just prior to application. Phosphorus and potassium had been mixed into the top 10 cm at the rate of 44 kg P/ha as triple super phosphate and 166 kg K/ha as muriate of potash. The plants were grown in a greenhouse.

Two different moisture regimes were maintained throughout the experiment. Periodic weights were taken on the columns to determine their moisture status. Particle size distribution was determined by the Bouyoucos Hydrometer Method. Moisture release characteristic curves were determined using the pressure plate technique. The high moisture treatment received water whenever the weight of the soil was equivalent to that at a 1 bar moisture

TABLE 6. NITROGEN TREATMENTS APPLIED AT THE RATE OF 400 KG/HA PRIOR TO PLANTING OATS.

Treatment	Nitrogen Source
1	Check
2	$Ca(NO_3)_2$
3	$(NH_4)_2SO_4$
4	$(NH_4)_2SO_4$ + 0.5% N-Serve*
5	$(NH_4)_2SO_4$ + 1.0% N-Serve*

* N-Serve was added as a percentage of the total nitrogen applied.

tension. The low moisture received water whenever the moisture tension dropped to 15 bar moisture tension. Water was applied to above field capacity to insure some degree of leaching and collection of effluent samples. Effluent samples were analyzed for nitrate using the Orion specific ion nitrate electrode in a buffer solution as described by Milham, Awad, Paull, and Bull (1970). Oats were harvested on March 6, April 9, and May 10. The first two cuttings were clipped at a 5-cm height to induce tillering. The final oat harvest included all above ground plant tissue.

Following the third cutting of oats, sweet sudan grass (Sorghum vulgare sudanense) was planted in the same manner as the oats. No additional fertilizer was applied. Sudan was harvested on June 19, and all above ground plant tissue was taken for yield and nitrogen analysis. Plant tissue was dried in a forced draft oven at 55°C then ground to pass a 60 mesh sieve. Nitrates were determined on the plant tissue using the same method as given previously. Protein-N was determined by digesting plant tissue in concentrated sulfuric acid along with selenized Kjeldahl granules and determining the ammonia by micro Kjeldahl.

Initial and final soil samples were dried at 55°C and ground to pass a 10 mesh sieve. Soils were extracted using 0.2 N K_2SO_4 and 0.05 N H_2SO_4 solution. Ammonium was determined by the Kjeldahl method and nitrates determined using the nitrate electrode method.

RESULTS

During this experiment, water was applied to the high moisture treatment 8 times and 6 times to the low moisture treatment. Rainfall was unusually high during this period which accounted for more cloudy days than would normally be expected during this season.

Figures 5 and 6 show the cumulative nitrate nitrogen collected in the

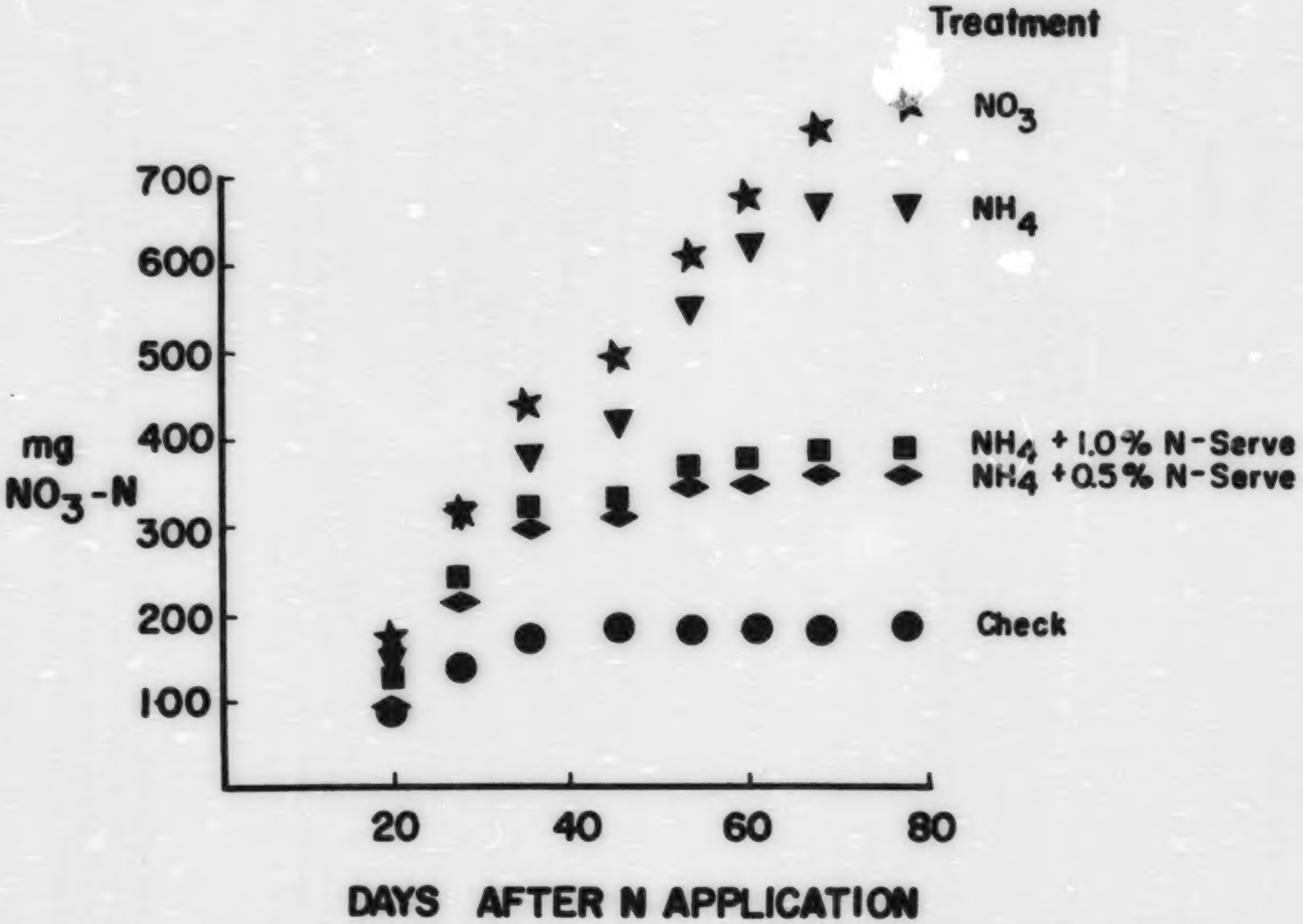

Figure 5. Accumulative nitrate-N in effluent from columns of Norwood silty clay loam maintained at high moisture level.

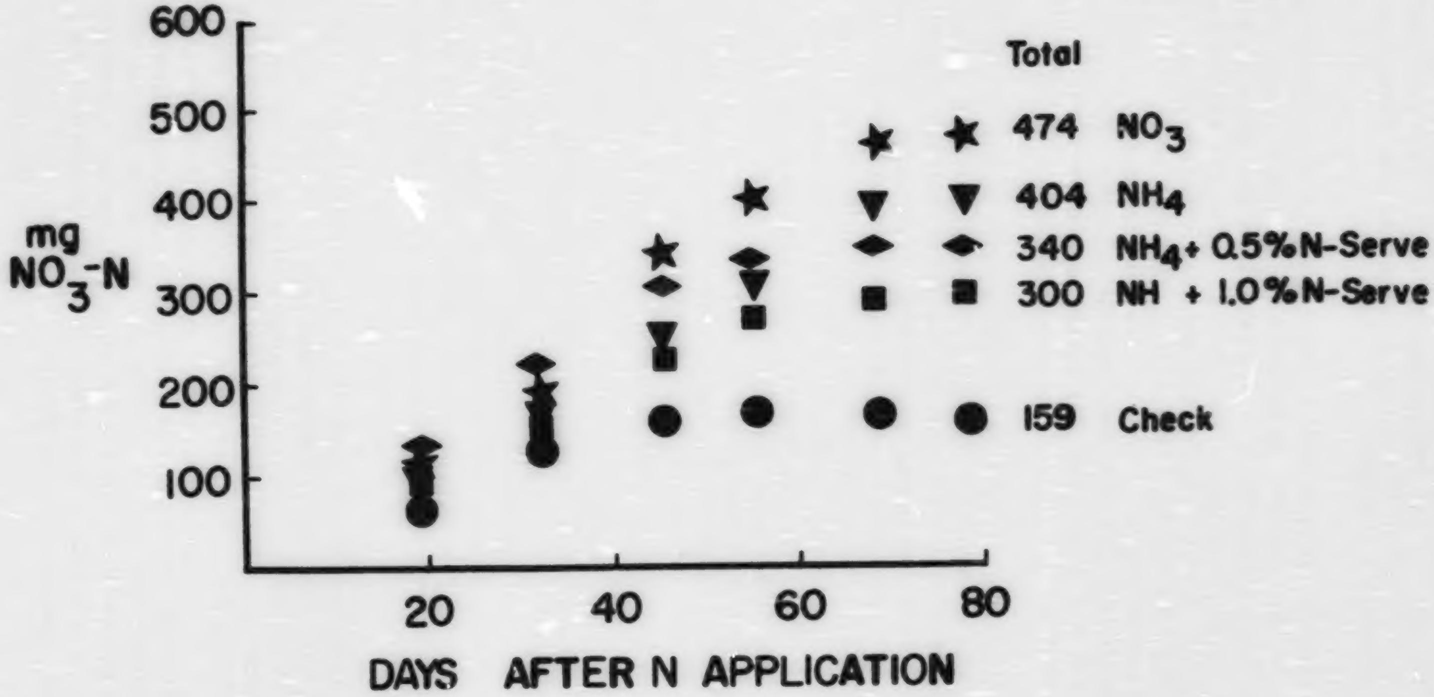

Figure 6. Accumulative nitrate-N in effluent from columns of Norwood silty clay loam maintained at low moisture level.

effluent samples from the different treatments. Each point represents an average over 3 replications. Under both moisture regimes total nitrate lost in the effluent was highest under the nitrate treatment and lowest in the ammonium treatments treated with N-Serve.

Nitrate-N lost from the high moisture treatment, where nitrate and ammonium were applied, was 326 and 245 mg greater respectively, than that collected from the low moisture treatments. Nitrate loss was only slightly higher in the high moisture treatment over the low moisture where ammonium was applied with N-Serve. Where N-Serve was applied with ammonium, the nitrate lost by leaching started to level off at 35 days while it took 68 days under the low moisture regime. In relation to the amount of total nitrogen applied, approximately 30% was lost in the leachate from the nitrate treatment while only 10% was lost from the ammonium with N-Serve treatment in the high moisture regime.

Figures 7 and 8 show the percent NO_3 in the plant tissue (oats) for each harvest and each moisture treatment. The nitrate and untreated ammonium treatment was not significantly different in the first cutting and NO_3 in the plant tissue from these treatments was approaching 1.0% which is a very critical level and could be expected to cause death of animals feeding on such forages. Nitrate accumulation was prevented by the addition of N-Serve to the ammonium fertilizer. Although both the 0.5% and 1.0% N-Serve treatments had low accumulation of NO_3, the 1.0% N-Serve treatment was the only treatment in which the nitrate-N was less than 0.5% in the plant tissue in both moisture treatments. Nitrate in the plant should ideally be less than 0.5%. Even in the second cutting nitrate-N in the plants grown on nitrate and ammonium (untreated) contained between 0.4 and 0.5% NO_3-N. The N-Serve treated ammonium again significantly reduced the accumulation on nitrate in the plants.

As can be seen in the graph, nitrate in the plant tissue was reduced by the higher rate of N-Serve in both moisture treatments. In the third harvest the values were very low and the accumulated nitrate remained highest in the nitrate treatment and all values were slightly higher in the low moisture treatment. Even though the nitrate in the plant was much lower where N-Serve treated ammonium had been applied to the soil this did not reduce protein production or yield.

Figures 9 and 10 show the yield data for each harvest under high and low moisture. In the high and low moisture treatment the yield for the nitrate treatment was always lower than the ammonium with N-Serve treatment. In the low moisture treatment there was no significant difference between any of the nitrogen treatments. However, the total yield in the ammonium with N-Serve treatments was slightly higher than where no N-Serve was applied. It should be pointed out that the reason for the large increase in yield for the third harvest was due to taking all the above ground material whereas in the first two harvests the plants were clipped at a 5-cm height. Yield was considerably less under low moisture for all treatments in the second and third harvest except for the check.

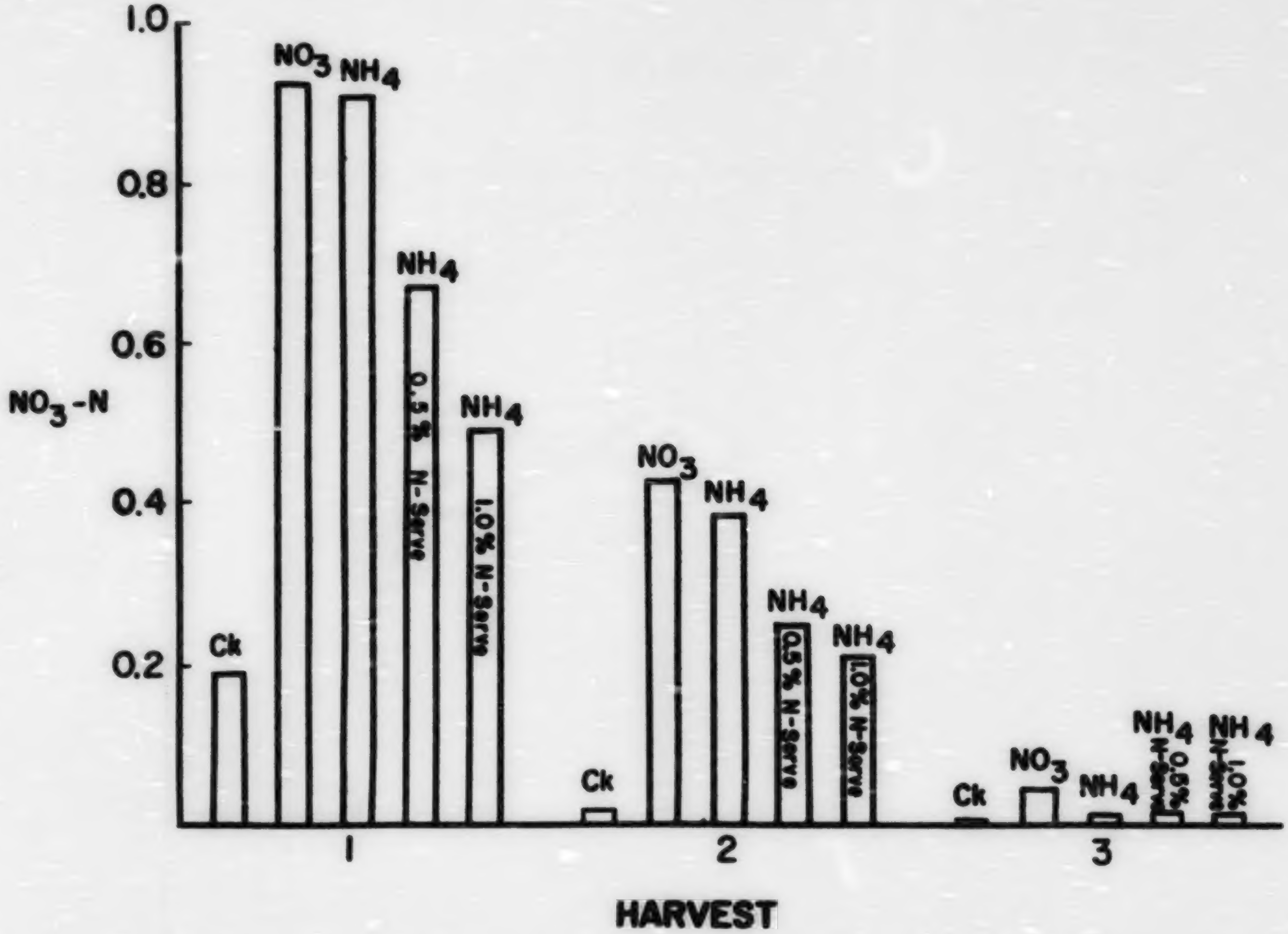

Figure 7. Nitrate in oat tissue from 3 harvests grown under high moisture conditions.

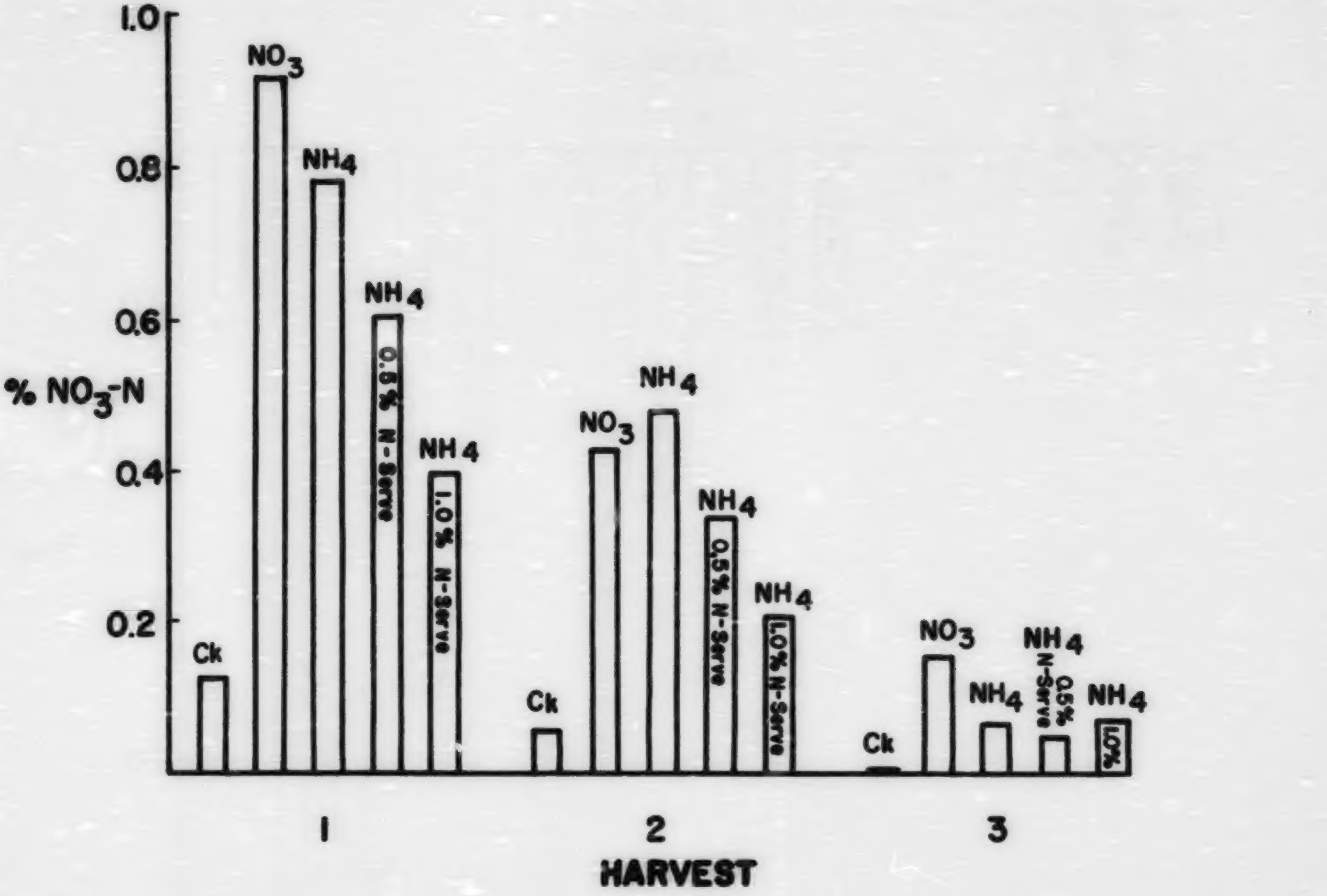

Figure 8. Nitrate in oat tissue from 3 harvests grown under low moisture conditions.

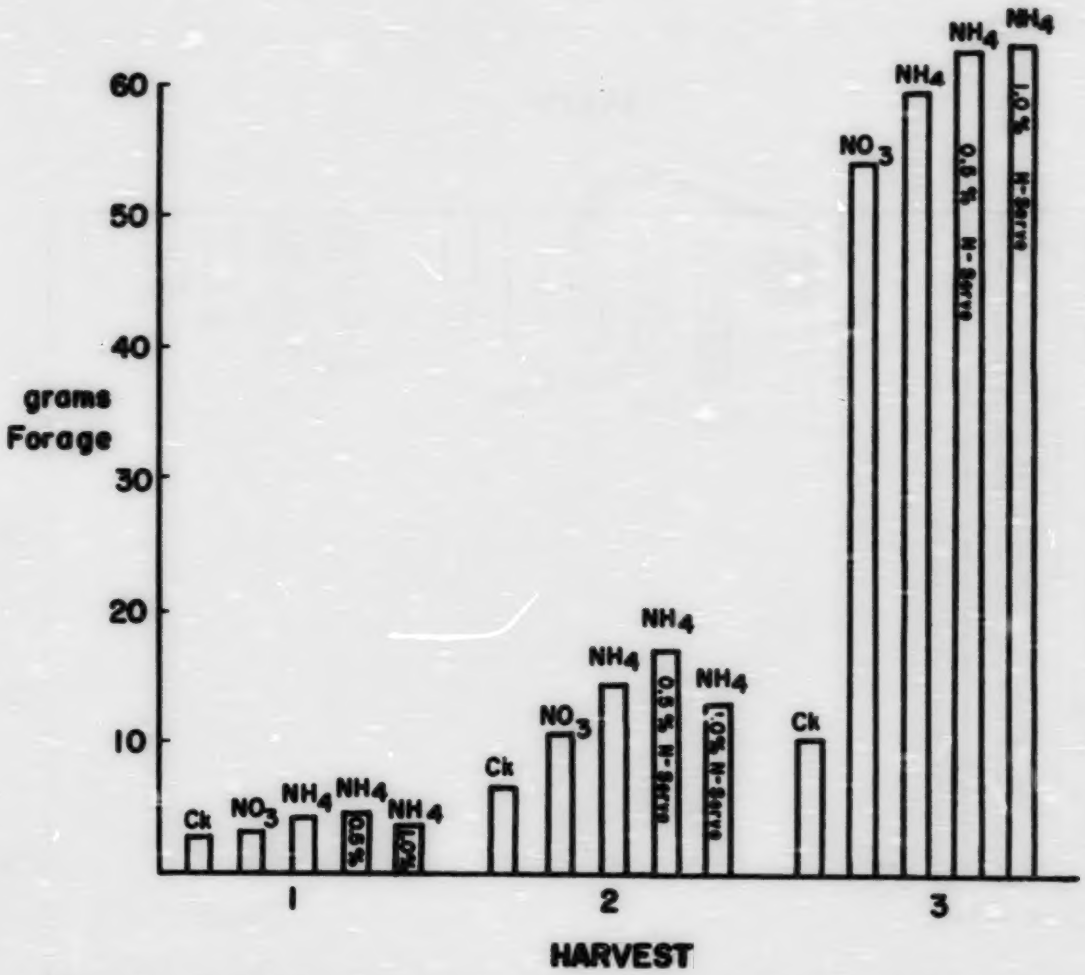

Figure 9. Yield of oats from 3 harvests grown under high moisture conditions.

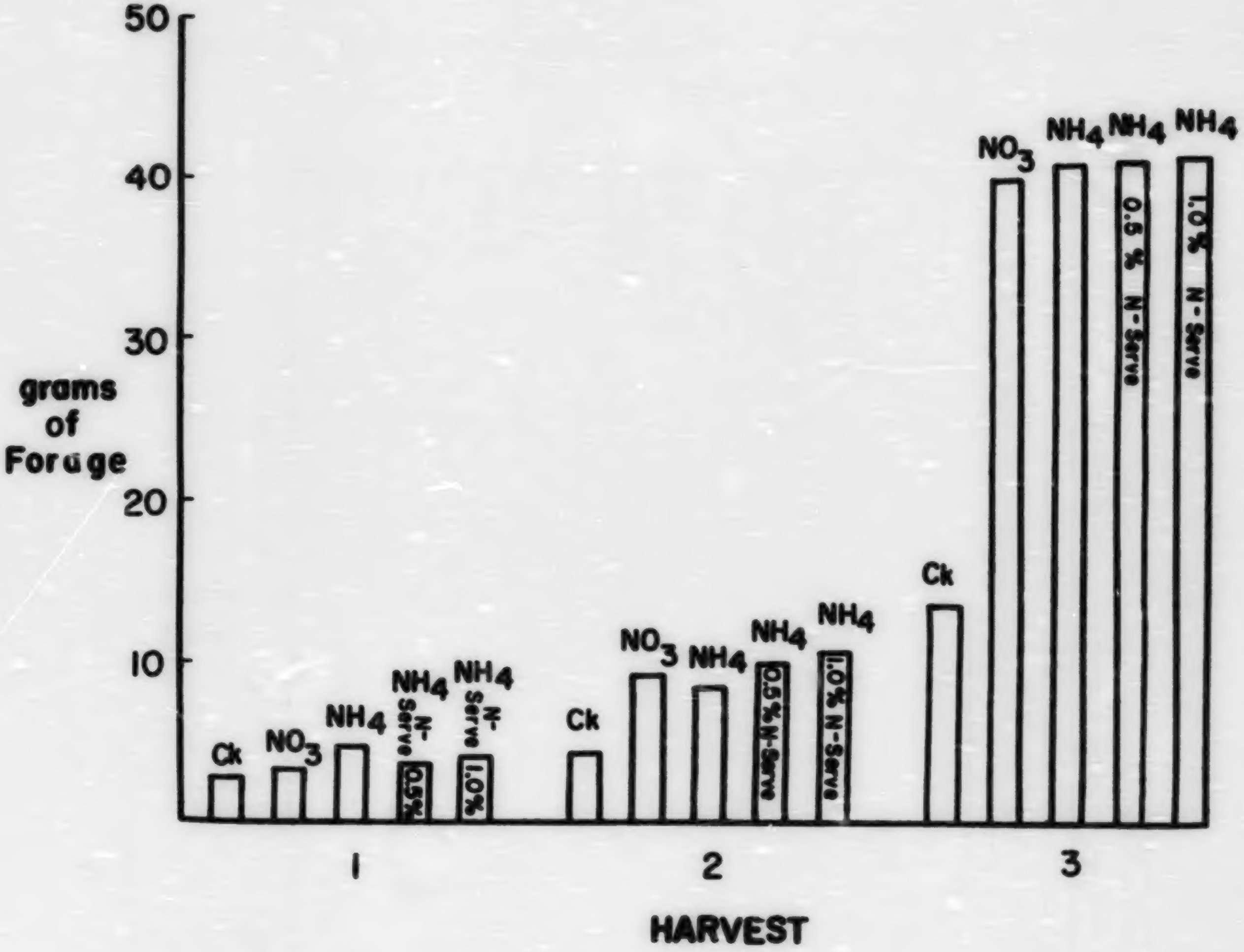

Figure 10. Yield of oats from 3 harvests grown under low moisture conditions.

Percent protein was not significantly different among nitrogen treatments in either moisture regime. The check had significantly lower protein in all harvests. Percent protein was higher in all treatments except the check of the third harvest in the low moisture treatment as compared to the third harvest of the high moisture treatment.

The efficiency with which nitrogen was utilized to synthesize protein is illustrated in Figure 11 for all treatments. Efficiency was 10% higher for all the ammonium treatments than the nitrate treatment. The average percent protein is much higher in the low moisture treatment because percent protein was similar or slightly higher in certain harvests than that in the high moisture. In this graph it would seem that ammonium without N-Serve would be just as efficiently used. However, it should be emphasized that this treatment lost more nitrate in the effluent and had higher concentration of nitrate in the plant tissue than did the ammonium with N-Serve.

Sudan grass was planted on May 15, 1973, to determine if any residual nitrogen remained in the soil. No additional fertilizer was applied. Moisture treatments were the same as when oats were grown. All of the above ground forage was harvested on June 19, 1973. During this period, nitrate in the effluent was below the level of detection for most samples and not significant in the samples that were recordable. In the high moisture treatment, the yield in all treatments was not significantly different from the check. Protein nitrogen and nitrate nitrogen was also extremely low and not significantly different from that found in the check. In the low moisture treatment, there seemed to be more residual nitrogen remaining after the final oat harvest.

The nitrogen balance sheet is given for the high and low moisture in Table 7 and 8, respectively. Nitrogen analysis is not recorded for the sudan phase in the high moisture treatment because none of the values were significant enough to report. The values reported in each category are averages over 3 replications minus that found in the check.

In the high moisture treatment, the nitrate lost in effluent under the nitrate treatment was perhaps the most striking disadvantage of the nitrate application. The nitrate lost in the ammonium without N-Serve treatment was also considerable. This was true for both moisture treatments. However, the nitrate and ammonium treatments alone lost almost half as much nitrate in the low moisture treatment.

Total nitrate accumulated in the plant was also higher where nitrate was applied in the high moisture treatment while nitrate was slightly higher for the ammonium without N-Serve treatment under low moisture. In both moisture regimes addition of N-Serve decreased the amount of nitrate in the plant tissue.

Another important aspect of this study was to find that a higher percentage of nitrogen was utilized for protein nitrogen. The nitrate treatment was lowest followed by ammonium alone. Both N-Serve treatments gave the highest totals in both moisture treatments.

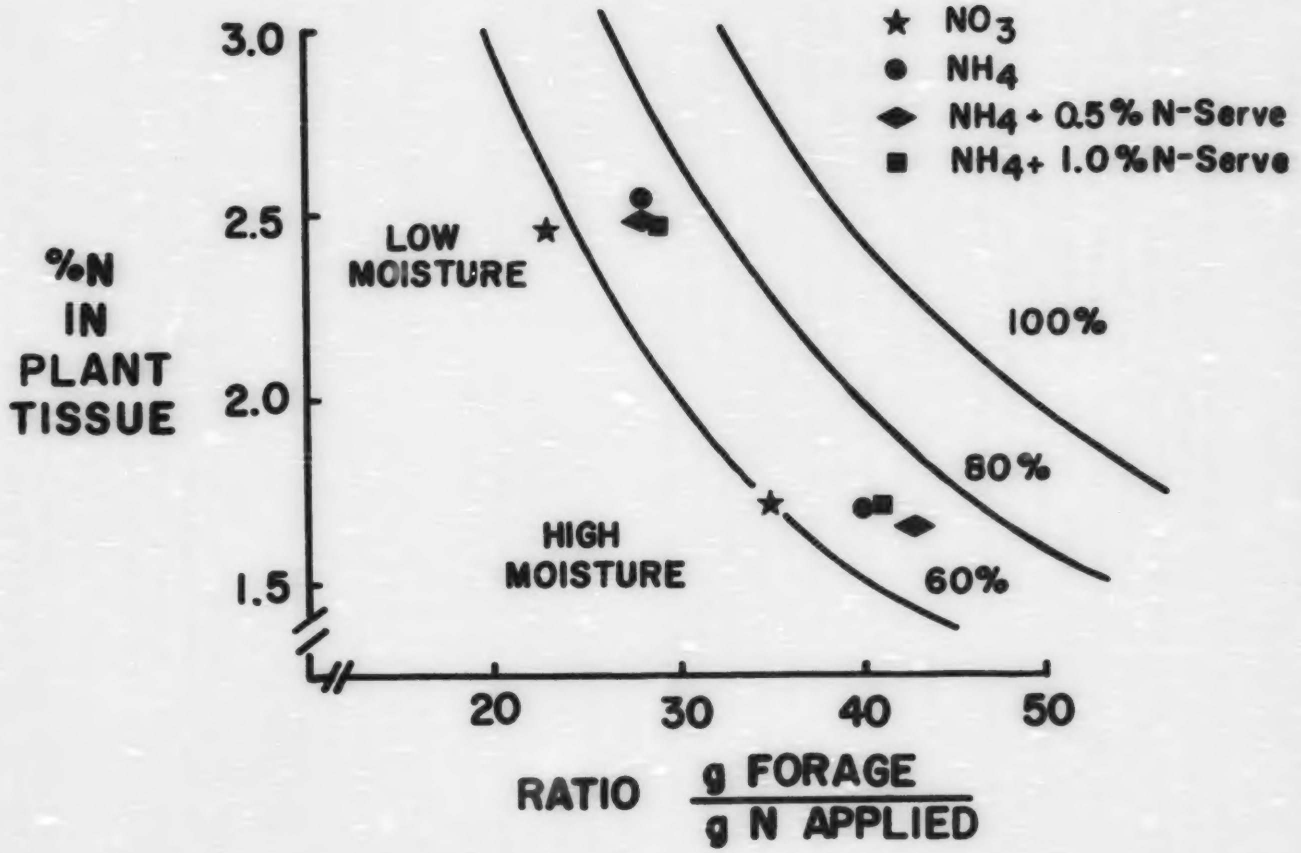

Figure 11. Nitrogen efficiency nomogram of protein nitrogen in oats grown under different moisture conditions and nitrogen sources.

TABLE 7. NITROGEN BALANCE SHEET FOR OATS GROWN UNDER HIGH MOISTURE TREATMENT.

	Treatments			
	NO_3	NH_4 +0.5%N-S	NH_4 +0.5%N-S	NH_4 +1.0%N-S
		mg		
Effluent NO_3-N	608	467	169	197
Plant (oats) NO_3-N	93	95	76	50
Protein N (Oats)	957	1082	1172	1153

TABLE 8. NITROGEN BALANCE SHEET FOR OATS GROWN UNDER LOW MOISTURE TREATMENT.

	Treatments			
	NO_3	NH_4	NH_4 +0.5%N-S	NH_4 +1.0%N-S
		mg		
Effluent NO_3-N	316	245	179	141
Plant (Oats) NO_3-N	127	78	72	62
Protein N (Oats)	861	1109	1111	1107
Plant (Sudan) NO_3-N	3	1	2	5
Protein N (Sudan)	41	19	31	83
Total N recovered as Protein N	902	1128	1142	1190

These results indicate that nitrification inhibitors could possibly reduce the amount of nitrate leaching through soils under field conditions.

SECTION 6

TIMING AND SOURCE OF NITROGEN APPLICATION

Field plots were established in the fall of 1973 to determine the effect timing of applying nitrogen fertilizers has on the uptake of nitrogen by grain sorghum. Fertilizer was applied as much as five months prior to planting. The properties of readily soluble and slowly soluble nitrogen sources were utilized to determine the effect these sources have on the movement of nitrates through the soil. The effectiveness of a nitrification inhibitor on preventing the movement of nitrogen through the soil was also determined.

PROCEDURE

The field plot locations were established on two soil types, Houston Black clay (Udic Pellustert) and Norwood silt loam (Typic Udifluent). Plots established on Houston Black clay were located at the Blackland Research Center near Temple, Texas. Norwood silt loam plots were initiated on the Brazos River flood plain at the Texas Agricultural Experiment Station research farm near College Station, Texas. Overall size at each experiment location was 0.57 ha and consisted of 231 plots. Plots were arranged in a randomized block design with individual plots being 4.0 m by 6.1 m. Plots consisted of 4 rows.

The year prior to initiation of this experiment, corn (*Zea mays*) was planted on the College Station location to eliminate the first year effect of cultivation. Prior to this time, this area had been pasture. The beds were not significantly disturbed during the entire course of the experiment.

The Houston Black clay location had been in a 3-year rotation for many years. The usual rotation was grain sorghum (*Sorghum vulgare*) followed by cotton (*Gossypium hirsutum L.*) followed by winter oats (*Avena sativa*). Previous crop grown on this location immediately prior to the establishment of this experiment was winter oats. Following incorporation of the winter oat residue by discing, the land was bedded on 100-cm centers. The beds received only a minimum amount of disturbance during the experiment.

Two readily soluble N fertilizers, $(NH_2)_4SO_4$ and urea, and two slowly soluble N fertilizers, sulfur-coated urea-20 (SCU-20) and sulfur-coated urea-30 (SCU-30), were selected to determine what effect N source might have on NO_3-N movement. The units 20 and 30 refer to the percentage of N which dissolves in hot water (38°C) during a 7-day incubation period. These fertilizers were applied in a band approximately 15-cm below the soil surface. A tractor powered, conveyer-belt type fertilizer applicator was employed to place fertilizer below the center of the bed. This resulted in the band being 5 to 10 cm below seed placement depth. Rate of application was 134 kg-N/ha with individual plots receiving only one application per year. Fertilizer applications were made monthly, if weather permitted, starting in October of each year and continuing through March. The N sources which were applied and dates of application are shown in Table 9. Fertilizer placement on the March application date (planting date) was not directly in the center of the bed. Placement was 10 cm to the side of the bed center. Grain sorghum was planted immediately following N application. Sidedress treatments, in which one-half of the N was applied at the time of planting, were also made using this placement location. The second one-half of the sidedress applications, which were made just prior to the boot stage of the grain sorghum, were subsurface band applied, approximately 5 cm deep and 25 cm to the side of the plants. To evualuate whether nitrifying or denitrifying conditions exist at lower depths in these soils during winter months, a deep placement of $(NH_4)_2SO_4$ with and without N-Serve was made approximately 25 cm below the top of the beds at each application time. By applying these fertilizers monthly, an evaluation was made of the effect timing of application had on each N source.

A nitrification inhibitor, 2-chloro-6 (trichloromethyl)-pyridine, (N-Serve), was evaluated to determine its effectiveness in retarding nitrification under field conditions. Each N source was applied with and without an N-Serve treatment (Table 10). To treat the fertilizer, N-Serve was mixed at a rate equilvalent to 1% of the N content. N-Serve was mixed with the fertilizer one day prior to actual application of each fertilizer.

Grain sorghum (Sorghum vulgare) was planted each year at both locations. Table 11 lists the dates and activities related to the management of the crop during the growing season. Top Hand (Conley Seed Company), at 9.4 kg/ha, was the grain sorghum variety planted on April 3, 1974, at the College Station location. Excel 606 was planted at the Temple location at 9.6 kg/ha on March 21, 1974. At planting, propazine was applied to assist in weed control. Each location was cultivated twice during early to midgrowth stages. In 1975, Pioneer 846 was planted on both locations at 7.9 kg/ha. The planting date for College Station was March 12 while the date for Temple was March 25. Propazine was again applied and followed by cultivation as needed. Planting and cultivation was accomplished using conventional farm equipment.

As sorghum plants approached the boot stage, tissue samples were taken to determine protein content. This was accomplished by taking the entire above ground portion of two plants from each plot. Samples were dried at 55°C, then ground to pass a 30 mesh sieve. A 0.5 g subsample was then digested in sulfuric acid for protein N content (Jackson, 1958). The digested samples were distilled by a micro-Kjeldahl unit, into boric acid which was later back-titrated with standardized sulfuric acid. Crude protein calculations were made by multiplying N content by 6.25.

Grain yield data were collected to determine efficiency of each treatment. When moisture content of the maturing grain reached a level below 14%, two rows, 3.35 m long, were hand harvested from each plot. Heads were placed

TABLE 9. DATES THAT VARIOUS FERTILIZER-N SOURCES* WERE APPLIED TO THE HOUSTON BLACK CLAY AND NORWOOD SILT LOAM EXPERIMENT LOCATIONS.

Houston Black clay		Norwood silt loam
	1973-1974	
November 16		November 19
December 19		December 17
February 13		February 18
March 21 (at planting)		April 3 (at planting)
March 21 (½) +		April 3 (½) +
June 6 (½)		May 22 (½)
	1974-1975	
October 18		October 18
November 19		November 19
December 20		December 20
February 21		February 21
March 25		March 12
March 25 (½) +		March 12 (½) +
May 19 (½)		May 20 (½)

* $(NH_4)_2SO_4$, urea, sulfer-coated urea-20 and sulfur-coated urea-30

TABLE 10. FERTILIZER TREATMENTS APPLIED AT THE HOUSTON BLACK CLAY AND NORWOOD SILT LOAM EXPERIMENT LOCATIONS.

Treatments
1. $(NH_4)_2SO_4$
2. Urea
3. Sulfur-coated urea (SCU-20)
4. Sulfur-coated urea (SCU-30)
5. $(NH_4)_2SO_4$ + N-Serve
6. Urea + N-Serve
7. SCU-20 + N-Serve
8. SCU-30 + N-Serve
9. $(NH_4)_2SO_4$ (deep placement)
10. $(NH_4)_2SO_4$ (deep placement) + N-Serve
11. Control

in burlap bags and stored until thrashed. At this time, seed weights were taken for yield calculations and subsamples for protein analysis were taken.

Monitoring of NO_3-N movement through soil profiles was accomplished by taking soil core samples. Houston Black clay samples were taken to a depth of 120 cm, while Norwood silt loam samples were taken to 150 cm. A hydraulically powered 5-cm diameter core tube was used to take the samples. Each soil core was sectioned into the following increments: 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm, 90-120 cm. Each subsample was placed in individual paper bags for drying. Two soil cores were taken from each plot. The 5-cm soil core was taken directly through the center of the bed. This resulted in sampling the area immediately in and below the fertilizer band. Even though only 134 kg-N/ha was applied the concentration of N in the core sample was considerably larger. This does not indicate that N throughout the soil profile is as concentrated as the area near the band.

Initial soil samples were taken at random over both locations prior to initiation of the treatments. Table 12 contains soil sampling dates.

As the soil samples were collected, they were placed in small paper bags and dried at 55°C in a forced air oven as soon as possible. There were times during the spring sampling period when enough ovens were not available to dry all the samples immediately. To alleviate this problem, the remaining samples were allowed to air dry under a high speed fan. Outdoor environmental conditions were such the samples dried within 12-24 hours.

After drying, the soils were ground to pass a 20 mesh sieve. A 40.0 g portion of each sample was extracted with 50 ml of 0.2 N K_2SO_4. The samples were placed on a mechanical shaker for 30 minutes before being filtered through a 10-cm Buchner funnel containing Whatman 42 filter paper. The extracted solution was immediately refrigerated to 2°C to await further analysis.

Nitrate N determinations were made on all soil samples using a modification of the phenoldisulfonic acid (Bremner, 1965) method. Rather than drying aliquots of the extracts in a beaker over a hot plate, as described in the original procedure, the aliquots were dried in a forced draft oven at 55°C overnight. Further investigation revealed temperatures as high as 120°C could be used to speed up drying time without causing loss of NO_3-N. Drying at 120°C allowed extract aliquots to be dried directly in 100 ml volumetric flasks. This permitted the omission of several time consuming transfer steps.

After addition of the phenoldisulfonic acid to the dried extract in the volumetric flasks, a small amount of distilled water was added to generate heat. The color was developed by making the solution basic with 1.2 N KOH and bringing to volume. The colorimetric determination was made using a Spectronic 20 at a wavelength of 420 mu.

Ammonium N concentrations were determined on all soil profiles to a depth of 60 cm during the winter sampling periods. At this time, NH_4-N concentrations were much higher than during the spring sampling period. After a

TABLE 11. ACTIVITIES AND DATES RELATED TO GRAIN SORGHUM GROWN ON TREATED PLOTS TO MONITOR N EFFICIENCY.

Activities	Date	Houston Black clay	Norwood silt loam
Planting: Grain sorghum was planted.	1974	March 21	April 3
	1975	March 25	March 12
Tissue samples: Plant tissue samples were taken at pre-boot to determine protein content.	1974	May 21	June 7
	1975	June 4	May 21
Harvest: Yield data was collected and subsamples taken for protein analysis.	1974	July 22	August 6
	1975	August [illegible]	July 23

TABLE 12. DATES SOIL SAMPLES WERE TAKEN FROM THE HOUSTON BLACK CLAY AND NORWOOD SILT LOAM EXPERIMENT AREAS, AND THE VARIOUS FERTILIZER TREATMENTS SAMPLED.

Houston Black clay		Norwood silt loam	
Sampling dates	Treatments sampled *	Sampling dates	Treatments sampled *
	Winter		Winter
1974: Feb. 7	Nov., Dec.	1974: Feb. 7	Nov., Dec.
1975: Jan. 21	Oct., Nov., Dec.	1975: Jan. 27	Oct., Nov., Dec.
	Spring †		Spring †
1974: May 22		1974: June 4	
1975: June 6		1975: May 21	

* All treatments applied at the application periods indicated were sampled.

† At this sampling, all application periods and treatments were sampled.

complete check of several profiles sampled in the spring, it was determined NH_4-N needed to be run on only the upper 30 cm. The deep placement treatments were analyzed for NH_4-N to a depth of 60 cm during every sampling period.

To determine NH_4-N concentration (Bremner, 1965), a 10 ml aliquot of the extracted solution was added to a micro-Kjeldahl unit (Labcon Co.). Five ml of 10 N NaOH was added to raise the pH of the distilling solution. Distillation was allowed to continue until approximately 20 ml of the distillate had been collected in a boric acid-indicator solution. The resulting solution was then titrated with standardized sulfuric acid.

An analysis was made to determine urea concentrations remaining in the sulfur-coated prill in the SCU-20 and SCU-30 treatments. This was accomplished following Keeney and Bremner's (1967) procedure for urea determination. The extracted urea was hydrolized by urease to NH_4-N. The NH_4-N was determined by the above described micro-Kjeldahl procedure.

RESULTS

Soil core samples were taken periodically to determine the relative amounts of NO_3-N leaching. Two soil cores were obtained from each plot during each sample period. These cores were taken through the center of the bed. Since the fertilizer was band applied, the core obtained was of the soil directly above and below the applied N. This resulted in very high N concentrations in the core segments that were from the immediate area of the band. This sampling technique will give an indication of the amount of N that had leached from the band into the lower depths of the profile, but will not give an estimate of the total amount of N in the entire profile of the soil. The measurements obtained should indicate the maximum NO_3-N concentration in the soil profile.

To determine the inherent N level of the plot areas, initial samples were taken to a depth of 150 cm at the College Station location and 120 cm at the Temple site. The College Station samples were collected November 20, 1973, while the Temple samples were taken November 23, 1973. Eleven soil profiles were analyzed at each site. The average of these determinations is given in Table 13. The exchangeable N level for the 150-cm profile at College Station was 45.9 kg-N/ha. Ammonium N constituted 16% of the N present. The maximum average NO_3-N level (2.5 ppm) occurred at the 0-15 cm depth, while the minimum (1.3 ppm) occurred at the 60-90 cm depth. No NH_4-N was found below 30 cm. Above this depth only very small amounts of NH_4-N (1.6 ppm) were detected.

The Houston Black clay site initially contained an average of 32.7 kg/ha exchangeable N. The maximum average NO_3-N concentration (2.1 ppm) occurred at the 0-15 cm depth. The lower depths (60-120 cm) had a very limited amount of NO_3-N present (0.9 ppm). The NO_3-N level for the 120-cm profile was only 20.8 kg-N/ha. The NH_4-N concentration for the upper 60 cm of the profile averaged less than 2 ppm. Below this depth no NH_4-N was detected. The NH_4-N fraction constituted 37% of the exchangeable N present.

TABLE 13. AVERAGE INITIAL EXCHANGEABLE N CONCENTRATION FOR HOUSTON BLACK CLAY AND NORWOOD SILT LOAM EXPERIMENT LOCATIONS.

Depth (inches)	Houston Black clay * NO_3-N	Houston Black clay * NH_4-N	Depth (inches)	Norwood silt loam † NO_3-N	Norwood silt loam † NH_4-N
	-------ppm----------			--------ppm--------	
0 - 6	2.1	1.8	0 - 6	2.5	1.4
6 - 12	1.4	0.9	6 - 12	1.6	1.6
12 - 24	1.2	1.2	12 - 24	1.5	
24 - 30	0.9		24 - 30	1.3	
30 - 48	0.9		30 - 48	2.3	
			48 - 60	1.6	
Total kg-N/ha	32.7			45.9	

* Sampled November 23, 1973

† Sampled November 20, 1973

Leaching and Nitrification During Fall and Winter

Houston Black Clay- 1974--

The various N sources were band applied, at 134 kg-N/ha, to a selected group of plots on November 19, and to a second group on December 17, 1973. The October application period was omitted due to adverse weather conditions which occurred during that month. The treated plots were sampled February 8, 1974, to determine the degree of leaching and nitrification during the fall and winter.

Relative amounts of exchangeable N are exhibited in Table 14. Generally, plots treated with a readily soluble N source contained larger amounts of exchangeable N. The only significant difference amoung sources was between the readily soluble and slow release forms. Due to slow dissolution rate of sulfur-coated urea, substantial amounts of applied N had not been released into the soil solution at the time of sampling. Although samples were not analyzed for urea, it is evident that considerable amounts of unhydrolyzed urea were present. This would explain low exchangeable N levels found in plots treated with sulfur-coated urea.

TABLE 14. TOTAL NO_3-N AND NH_4-N IN 120-CM PROFILES OF HOUSTON BLACK CLAY AFTER RECEIVING 134 KG-N/HA. SAMPLING DATE, FEBRUARY 8, 1974

	Time of application					
	November			December		
Treatment	NO_3-N*	NH_4-N	Sum	NO_3-N	NH_4-N	Sum
	kg-N/ha					
Am Sul	429	21	450	267	167	431
Am Sul + N-Serve	143	329	473	67	22	90
Urea	636	213	849	220	76	296
Urea + N-Serve	270	455	725	99	31	130
SCU-20	180	152	333	136	38	174
SCU-20 + N-Serve	103	440	543	180	87	268
SCU-30	192	62	253	156	78	234
SCU-30 + N-Serve	124	348	473	63	124	187
Am Sul (deep)	511	43	552	217	190	408
Am Sul + N-serve (deep)	227	129	356	67	110	177
Average	281	179	501	147	92	239
Control	38	18	56	40	35	75

* Average of six profiles consisting of five sampling depths

Amounts of exchangeable N present (Table 14) were significantly affected by time of application. Average exchangeable N for November applied treatments was 501 kg-N/ha while December treatments contained 239 kg-N/ha. No apparent reason for the 53% decrease can be obtained from data collected.

Nitrate is the major form of N susceptable to denitrification. If denitrification caused the observed differences, then a major portion of the November applied N should have been denitrified. One plausible explanation why the November applied N was not denitrified could be it was immobilized and was present in an organic form when the December applied N, which was nitrified, was subjected to denitrifying conditions. Another point to consider is the effect of N-Serve. Losses in December treatments tended to be greater when N-Serve was included. N-Serve decreased NO_3-N and increased NH_4-N. This factor would tend to indicate that denitrification was not the major source of N loss.

As discussed earlier, volatilization could be involved in the N loss that occurred. Ammonia is the major form of N lost in this manner. Since N-Serve was highly active during December, addition of N-Serve could have caused a substantial increase in N loss due to volatilization. However, it has also been reported (Jansson, 1958) that NH_4-N is more readily immobilized by microorganisms than NO_3-N. Since total N was not determined in these soils this could not be verified.

Although N-Serve had little effect on amounts of exchangeable N present at the February sampling of the November application, it did reduce the amount of soluble N found in the December sampling. However, N-Serve was highly effective in maintaining the N in the NH_4-N form (Table 14). The result of this highly significant effect is apparent in Table 15. When N was maintained in the NH_4-N form very little leaching occurred. This is evident by observing relative amounts of NO_3-N below 60 cm in $(NH_4)_2SO_4$ + N-Serve treatments. Average content of the latter treatment was 1.2 ppm while the former contained 6.1 ppm NO_3-N.

When considering leaching, the readily soluble N forms exhibited the greatest amount of leaching. The least amount of leaching occurred in the sulfur-coated urea plots that were treated with or without N-Serve. The latter treatments exhibited NO_3-N levels at 60-120 cm depths very similar to those observed in control plots.

Houston Black Clay-1975--

During the second year of the study applications of fertilizer were made October 18, November 19, and December 20, 1974. Each treatment again received 134 kg-N/ha. The following January 21, 1975, soil cores were taken to a depth of 120 cm on treated plots. In addition to NO_3-N and NH_4-N analysis, urea N was determined on samples from plots treated with sulfur-coated urea.

The data collected during this time interval is very similar to the 1974 data. However, some differences were obtained and will be discussed.

Total exchangeable N values are listed in Table 16. Source of N had a significant effect on resulting N values only when readily soluble sources were compared. As previously discussed, differences were due to the dissolution rate of sulfur-coated urea. During 1974, no urea N analysis was performed on soil samples obtained from the slow release treatments; however, in 1975, this analysis was made. There was no significant difference between the dissolution rate of SCU-20 and SCU-30 during this sample period. Therefore, they will be considered jointly. These results indicate that approximately 54% of the urea N had not hydrolyzed from the sulfur-coated prills. This percentage value is obtained by considering the initial concentration of urea N in the fertilizer band and the area of the soil sampling tube.

TABLE 15. CONCENTRATION OF NO_3-N IN PROFILES OF HOUSTON BLACK CLAY AFTER RECEIVING 134 KG-N/HA. SAMPLED ON FEBRUARY 8, 1974

Depth	Am Sul	Am Sul + N-s*	Urea	Urea +N-s	SCU-20	SCU-20 + N-s	SCU-30	SCU-30 + N-s	Am Sul (deep)	Am Sul + N-s(deep)	Control
cm	ppm										
	Application date:. November 19, 1973										
0- 15	48.6	21.2	135.8	43.1	42.2	8.3	41.0	25.7	107.6	36.6	5.7
15- 30	90.4	28.2	105.8	48.7	27.1	14.3	33.6	17.1	64.8	37.3	3.9
30- 60	14.4	4.6	17.7	11.0	3.2	2.3	4.8	3.4	16.1	10.1	2.0
60- 90	4.6	1.5	2.7	1.8	2.1	1.4	0.8	1.7	5.2	1.7	0.9
90-120	7.7	1.0	0.5	1.5	0.4	0.8	1.4	1.2	6.4	2.0	0.8
	Application date: December 17, 1973										
0- 15	72.1	8.5	45.4	10.7	30.6	58.1	40.1	7.5	9.2	3.5	3.5
15- 30	31.1	11.6	28.9	11.4	18.1	10.5	20.7	8.9	60.0	14.0	3.9
30- 60	5.3	3.4	9.7	7.9	3.5	2.8	2.7	3.1	11.2	2.9	3.0
60- 90	1.2	0.8	0.6	1.5	1.5	1.7	0.9	1.9	1.6	2.0	1.3
90-120	1.2	0.7	1.0	1.5	1.5	1.3	0.6	0.7	1.0	1.4	0.9

* N-s = N-Serve

TABLE 16. TOTAL NO_3-N AND NH_4-N IN 120-CM PROFILES OF HOUSTON BLACK CLAY AFTER RECEIVING 134 KG-N/HA. SAMPLED ON JANUARY 21, 1975*

Treatment	October		November		December	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
	kg-N/ha					
Am Sul	478	0	319	34	73	175
Am Sul + N-Serve	123	102	137	73	72	269
Urea	391	0	404	3	285	133
Urea + N-Serve	131	73	97	31	82	385
SCU-20	183	34	158	5	87	89
SCU-20 + N-Serve	85	21	93	73	118	40
SCU-30	259	18	474	18	73	68
SCU-30 + N-Serve	235	91	421	124	107	84
Am Sul (deep)	498	0	340	14	59	138
Am Sul + N-Serve (deep)	120	49	131	66	72	142
Average	250	39	257	44	103	152

Time of application

* The control for this sample date averaged 73.9 kg-N/ha

Since less N was released, it is reasonable to assume less exchangeable N would be present in the soil solution at sampling time. The collected data agrees with this assumption.

Nitrogen source influenced NO_3-N leaching. Urea and $(NH_4)_2SO_4$ were not significantly different as an N source nor was SCU-20 and SCU-30, consequently, they can be considered jointly. By comparing NO_3-N leaching for the readily soluble sources, a considerable difference is observed. In the October applied readily soluble treatments, the soil below 60 cm contained 16.6 ppm NO_3-N while the slow release forms contained only 12.1 ppm (Table 17).

The various times of fertilizer application had only limited effect on resulting total exchangeable N levels per profile. The average of all treatments applied in October is 289 kg/ha exchangeable N. November and December treatments contained 301 and 255 kg/ha exchangeable N, respectively (Table 16). It is interesting to note the lowest average value obtained was from the December applied treatments. This unusually low December value was also observed in 1974.

Nitrate N leaching was influenced by time of application. Generally, the longer the time interval, from fertilizer application to sampling, the greater the amount of leaching. Maximum time of application effect was observed on readily soluble sources not treated with N-Serve. These treatments averaged 16.9, 12.2, and 7.0 ppm NO_3-N below 60 cm for October, November, and December application periods, respectively (Table 17). When nitrification was inhibited by addition of N-Serve or a slow release source was applied, time of application did not substantially influence the amount of NO_3-N below 60 cm. Overall, December applied treatments exhibited the least NO_3-N below 60 cm. This fact may be only indirectly releated to time of application, since the total exchangeable N level of December applied treatments was always lower than the other application dates.

N-Serve caused several significant effects on the N content and distribution in the various profiles. Generally, the N-Serve effect was very similar to the results reported in 1974. Briefly, N-Serve decreased leaching and decreased nitrification. In all cases, adding N-Serve to the fertilizer treatment decreased the amount of NO_3-N present below 60 cm (Table 17). The maximum N-Serve versus leaching effect was in the readily soluble treatments. These sources applied in October, November, and December averaged 16.9, 12.2, and 7.0 ppm NO_3-N below 60 cm, respectively. When these sources were treated with N-Serve, respective NO_3-N levels were 11.9, 9.3, and 5.8 ppm. This is a decrease in leaching of 30, 24, and 17%, respectively. When N-Serve was included in sulfur-coated urea treatments, the decrease in leaching was not as dramatic.

N-Serve effect on leachability can be directly related to nitrification. In plots treated with $(NH_4)SO_4$, 90% of the exchangelable N present at sampling was in the NO_3-N form. When N-Serve was included in this treatment only 65% of the exchangeable N was as NO_3-N. When this source was applied in October, no NH_4-N was present at sampling. When N-Serve was included, 55% still remained in NH_4-N. Other sources responded similarly. This data indicated N-Serve was active as a nitrification inhibitor for the duration of this test.

The addition of N-Serve to the readily soluble N sources resulted in less exchangeable N being present at sampling. In the October and November application periods, N-Serve decreased exchangeable N by 51 and 56%, respectively, while in the December period, it increased exchangeable N by 20%. This could be explained by the fact NH_4-N is more readily immobilized by microorganisms as reported by Jansson (1958). This effect was not observed in 1974. Another possible cause could be NH_4-N volatilization. Since the NH_4-N was held in high concentration near the fertilizer band, volatilization could have occurred. No data has been collected to substantiate this

TABLE 17. CONCENTRATION OF NO_3-N AND NH_4-N IN 120-CM PROFILES OF HOUSTON BLACK CLAY ON JANUARY 21, 1975, AFTER RECEIVING 134 KG-N/HA

Treatment and depth	Time of application					
	October		November		December	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm					
Am Sul						
0- 15	11.0	0	18.3	13.0	7.4	82.5
15- 30	31.7	0	45.4	3.1	2.2	0
30- 60	59.5	0	25.5	0	4.0	0
60- 90	20.1	ND	9.0	ND	3.5	ND
90-120	14.5	ND	10.2	ND	5.2	ND
Am Sul + N-Serve						
0- 15	2.5	44.7	2.6	31.8	3.4	86.7
15- 30	4.4	2.0	6.1	2.4	2.4	40.1
30- 60	11.5	1.2	8.5	0	4.5	0
60- 90	6.2	ND	8.0	ND	4.0	ND
90-120	8.5	ND	7.7	ND	6.1	ND
Urea						
0- 15	9.0	0	21.6	1.6	18.2	62.6
15- 30	16.6	0	25.1	0	3.9	0
30- 60	48.5	0	44.2	0	38.5	0
60- 90	19.5	ND	15.7	ND	12.7	ND
90-120	13.7	ND	14.2	ND	6.7	ND
Urea + N-Serve						
0- 15	3.6	34.4	14.7	27.1	3.0	171.2
15- 30	3.9	0	8.8	4.1	2.1	10.5
30- 60	9.7	0	25.2	0	4.0	0
60- 90	8.7	ND	12.5	ND	5.5	ND
90-120	9.5	ND	9.2	ND	7.7	ND
SCU-20						
0- 15	4.3	13.0	5.6	2.5	3.9	42.2
15- 30	7.8	2.8	8.2	0	2.2	0
30- 60	17.0	0	13.7	0	5.5	0
60- 90	13.7	ND	9.0	ND	6.0	ND
90-120	7.5	ND	8.6	ND	6.5	ND
SCU-20 + N-Serve						
0- 15	1.5	9.9	2.2	32.4	2.3	18.7
15- 30	1.5	0	3.6	2.0	12.2	0
30- 60	6.5	0	18.0	0	5.5	0
60- 90	6.5	ND	10.7	ND	7.5	ND
90-120	6.0	ND	9.5	ND	8.2	ND
SCU-30						
0- 15	8.2	6.9	15.1	8.4	4.4	27.8
15- 30	10.3	0	16.7	0	2.0	0
30- 60	26.2	0.8	27.5	0	4.2	2.1
60- 90	17.2	ND	12.5	ND	4.5	ND

Table 17. (Continued)

Treatment and depth	October		November		December	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm					
SCU-30 (Continued)						
90-120	10.0	ND	58.7	ND	5.7	ND
SCU-30 + N-Serve						
0- 15	2.1	42.8	1.8	56.5	20.0	39.4
15- 30	5.1	0	4.9	2.1	2.4	0
30- 60	24.3	0	15.8	0	5.1	0
60- 90	16.1	ND	11.3	ND	4.8	ND
90-120	8.7	ND	8.0	ND	5.0	ND
Am Sul (deep)						
0- 15	2.2	0	15.2	4.0	3.8	59.9
15- 30	27.5	0	28.6	2.8	2.7	5.0
30- 60	70.5	0	38.0	0	3.5	0
60- 90	22.2	ND	15.7	ND	2.5	ND
90-120	13.0	ND	6.2	ND	5.0	ND
Am Sul + N-Serve (deep)						
0- 15	1.3	11.7	2.2	17.2	1.7	55.9
15- 30	3.4	6.2	3.0	14.1	2.1	11.0
30- 60	9.7	2.6	13.0	0	5.5	0
60- 90	10.5	ND	8.0	ND	4.7	ND
90-120	6.5	ND	8.2	ND	5.2	ND
Control			NO_3-N	NH_4-N		
0- 15			2.6	23.1		
15- 30			2.3	0.3		
30- 60			1.3	0.9		
60- 90			0.9	ND		
90-120			0.9	ND		

statement. However, it must be remembered the fertilizer N was applied several centimeters below the soil surface. This N-Serve effect was not observed in sulfur-coated urea treatments.

Norwood Silt Loam-1974--

Fertilizer applications were made November 16 and December 19, 1973, on the Norwood silt loam plots. The October application period was omitted due to adverse weather conditions which prevented entrance into the plot area. Treated plots were sampled to a depth of 150 cm on February 6, 1974.

The results obtained for the November and December application were similar to those obtained from the Houston Black clay location during the same time interval. The effect of N source was not detectable except between readily soluble and the slow release forms. The readily soluble forms resulted in higher exchangeable N (Table 18) levels in the profile. Also, movement of NO_3-N to the lower depths of the profile (Table 19) was greater for the readily soluble treatments.

Whether the N was applied in November or December did not affect the amount of soluble N found in the profiles during February for the readily soluble sources. There was somewhat more NO_3-N in the profiles fertilized in November with the readily soluble forms not treated with N-Serve (Table 18). This is a result of a longer period for nitrification to occur.

When considering leaching, the concentration of NO_3-N at 60-90 cm was greater in all the November treated plots as compared to control plots or the December treatments (Table 19). This indicates some leaching of NO_3-N to at least 90 cm had occurred in the 82 days prior to February 6. Concentrations of NO_3-N below 60 cm in plots fertilized in December were similar to the control plots at similar depths. There was a slight increase in NO_3-N concentration in the 30-60-cm depth. This signifies little or no movement of NO_3-N below 30 cm between December 19, 1973 and February 6, 1974, in the Norwood silt loam soil. This limited amount of leaching can be attributed to the small amount of rainfall received in December and January. During this period only 11.5 cm of precipitation fell. No substantial rainfall had been received since October, therefore, the soil was dry and when precipitation did occur no runoff or deep percolation resulted.

In every N-Serve treatment, regardless of N source, NO_3-N concentrations were lower than in non-treated plots (Table 18). For the November application treatments, the NO_3-N level in the profiles treated with N-Serve averaged 101 kg-N/ha for all sources. For the same application period, but without the N-Serve treatments, the NO_3-N levels averaged 201 kg-N/ha. N-Serve resulted in a 50% reduction in NO_3-N content and a corresponding 54% increase in NH_4-N. Movement of N to the lower depths of the profile (Table 19) was also reduced by the addition of N-Serve. However, since no substantial amounts of leaching occurred in any of the treatments, the difference caused by N-Serve was not significant.

Norwood Silt Loam-1975--

During the second year of the study, fertilizer applications were made on October 18, November 19, and December 20, 1974. The following January 27, 1975, soil samples were taken to a depth of 150 cm.

The source of N, as has been the case in previous sections, exhibited a significant effect only when the readily soluble and slow release sources are compared. The readily soluble sources averaged 779 kg/ha of exchangeable N while the slow release forms averaged 578. When the various sources are compared as to leachability, $(NH_4)_2SO_4$ and urea leached more than sulfur-coated urea. These differences are directly due to dissolution rate. The slow release sources maintained less N in the soil solution thereby decreasing the potential for NO_3-N leaching.

TABLE 18. TOTAL NO_3-N AND NH_4-N IN 150-CM PROFILES OF NORWOOD SILT LOAM ON FEBRUARY 6, 1974, AFTER APPLYING 134 KG-N/HA ON NOVEMBER 16, 1973, AND DECEMBER 19, 1973.

	Time of application					
	November			December		
Treatment	NO_3-N	NH_4-N	Sum	NO_3-N	NH_4-N	Sum
	kg-N/ha					
Am Sul	274	170	444	153	147	300
Am Sul + N-Serve	114	599	713	113	450	563
Urea	264	396	660	151	632	783
Urea + N-Serve	127	1210	1337	130	792	922
SCU-20	120	1203	1323	102	179	281
SCU-20 + N-Serve	80	302	382	59	249	308
SCU-30	181	410	591	85	911	996
SCU-30 + N-Serve	75	253	328	76	627	703
Am Sul (deep)	166	101	267	161	232	393
Am Sul + N-Serve (deep)	109	1826	1935	88	727	815
Average	151	647	798	112	495	606
Control	90	217	307	80	224	304

Much of the sulfur-coated urea remained in the undissolved prill as indicated by the high N values found in 1974 (Table 19). Averaging the results of this sampling period indicates that 1,245 kg urea-N/ha was present at sampling on January 27, 1975. This urea was apparently still in undissolved prills and was unavailable for hydrolysis.

Time of application influenced the amount of exchangeable N present and the degree of leaching. The total exchangeable N (urea N included) present in the 150-cm profiles is shown in Table 20. The treatments applied in October, November, and December averaged 1,010, 1,416, and 895 kg-N/ha,

TABLE 19. CONCENTRATION OF NO_3-N IN 150-CM PROFILES OF NORWOOD SILT LOAM WHEN SAMPLED FEBRUARY 6, 1974, AFTER RECEIVING 134 KG-N/HA IN NOVEMBER AND DECEMBER

Depth	Am Sul	Am Sul + N-s	Urea	Urea +N-s	SCU-20	SCU-20 + N-s	SCU-30	SCU-30 + N-s	Am Sul (deep)	Am Sul + N-s(deep)	Control
cm	ppm										
	Application date: November 16, 1973										
0- 15	38.5	11.9	21.6	5.4	9.6	2.8	19.5	19.5	4.6	5.1	4.0
15- 30	17.8	12.8	37.7	10.4	13.4	5.5	22.8	22.8	15.0	9.8	8.4
30- 60	8.4	5.2	13.7	7.1	6.7	4.3	7.2	7.2	13.9	5.5	5.3
60- 90	11.8	3.2	8.4	6.3	3.3	2.7	4.6	4.6	5.5	2.7	2.9
90-120	4.0	2.5	3.6	4.4	3.2	3.3	3.6	3.6	3.7	3.2	2.6
120-150	8.8	2.1	3.1	2.5	1.9	3.2	3.9	3.9	4.1	5.2	3.1
	Application date: December 19, 1973										
0- 15	27.3	8.6	28.3	18.7	9.8	2.8	10.2	5.0	8.8	9.0	5.1
15- 30	16.6	7.3	17.4	14.5	10.2	4.2	7.3	5.9	20.0	4.6	6.9
30- 60	4.5	3.9	3.4	6.4	3.3	2.9	2.8	3.8	7.9	3.6	3.8
60- 90	3.7	2.8	2.4	2.8	3.6	2.8	2.8	2.9	3.4	2.4	3.5
90-120	2.0	5.4	2.5	2.0	3.3	1.7	2.8	2.4	3.6	2.0	2.8
120-150	1.9	5.1	2.3	1.2	2.9	2.3	1.8	2.1	6.1	5.0	1.8

TABLE 20. TOTAL OF THE NO_3-N, NH_4-N, AND UREA-N* IN 150-CM PROFILES OF NORWOOD SILT LOAM ON JANUARY 27, 1975, AFTER RECEIVING 134 KG-N/HA

Treatment	Time of application October	 November	 December	 Average
	------------------	kg-N/ha	------------------	
Am Sul	562	1230	739	844
Am Sul + N-Serve	465	781	690	645
Urea	737	981	837	852
Urea + N-Serve	771	814	737	774
SCU-20	1307	2261	994	1520
SCU-20 + N-Serve	2535	2607	927	2023
SCU-30	2230	2387	1624	2080
SCU-30 + N-Serve	961	2035	1104	1367
Am Sul (deep)	194	540	783	506
Am Sul + N-Serve (deep)	346	521	519	462
Average	1010	1416	895	1107
Control				87

* The presence of urea was determined on the SCU's only

respectively. Those fertilized in December contained 11% less than their October counterpart and 37% less than those fertilized in November. The 1974 data also indicates the December application averaged significantly less than the other application periods sampled in January. It is interesting to point out the average exchangeable N level for the November and December treatments sampled in 1974 was 702 kg-N/ha, while in 1975 these sample plots contained an average of 1,155 kg-N/ha. This is an increase of 60%. This indicates some of the N fertilizer applied the previous year was still present in the profile in 1975.

The relative amounts of leaching that occurred due to the various times of application is demonstrated in Table 21. The October applied fertilizer had moved a greater distance into the soil profile than those more recently applied. To demonstrate this, one may compare the relative amounts of NO_3-N below 60-cm in the October and December applied urea treatments. The former contained 8.8 ppm NO_3-N below 60-cm while the latter application period averaged only 2.5 ppm.

The various concentrations of NH_4-N in the profiles indicate the effect of N-Serve on the treatments. When N-Serve was not mixed with the N source, the fraction of the exchangeable N that was in the NH_4-N form at the time of sampling was 16%, 32%, and 58%, respectively, for the October, November, and December application dates. When N-Serve was included the respective NH_4-N percentages were 70, 71, and 70. This indicates the activity of N-Serve was substantial even after being in the field for 101 days. By maintaining the N mainly in the NH_4-N form, N-Serve caused a significant decrease in leaching in the treatments applied in October. This effect is exemplified in the October applied $(NH_4)_2SO_4$ treatment which averaged 9.5 ppm NO_3-N below 60-cm without N-Serve and 4.1 ppm with N-Serve. Since the amount of leaching in the November and December applied treatments was limited, the N-Serve affect was not apparent.

Leaching and Nitrification During Spring

Houston Black Clay-1974--

Fertilizer applications were made at the Houston Black clay site on November 16 and December 19 in 1973, and February 13, March 21, and as a split application on March 21 and June 6 in 1974. The March applications were made at the time the grain sorghum was planted. Soil samples were taken on all treated plots May 29, 1974.

The influence of N source on exchangeable N contained in the various profiles can be viewed in Table 22. Source effect is best illustrated when considered independent of time of application. If viewed in this manner, $(NH_4)_2SO_4$ and urea are insignificantly different in all respects. Compared to these sources SCU-30 averaged 16% less exchangeable N present in the profile at sampling. Sulfur-coated urea-20 averaged 57% less exchangeable N present. This would be expected since it is the least soluble of the N sources. The differences between SCU-30 and the readily soluble sources are due to their respective dissolution rates. During the winter sampling, no significant differences between SCU-20 and SCU-30 were observed. However, during the May, 1974 sampling, a sizeable difference was disclosed. Apparently the relative dissolution rates of these two slow release sources differ only slightly during periods when the soil temperatures are low, but become quite different during warmer weather. Since SCU-30 appeared more similar to $(NH_4)_2SO_4$ and urea than to SCU-20 (Table 22), one may conclude the dissolution rate of SCU-30 was greatly enhanced by the warmer spring temperatures. These statements of probable cause cannot be substantiated since no urea analysis was performed on samples taken in 1974 to determine the amount of N remaining in the sulfur-coated prills.

TABLE 21. CONCENTRATION OF NO_3-N AND NH_4-N IN 150-CM PROFILES OF NORWOOD SILT LOAM ON JANUARY 27, 1975, AFTER RECEIVING 134 KG-N/HA

	Time of application					
	October		November		December	
Depth	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm					
Am Sul						
0- 15	73.3	5.5	123.0	127.9	48.9	124.2
15- 30	79.9	0	127.1	58.1	10.5	16.7
30- 60	25.0	0	23.6	0	5.8	2.0
60- 90	12.6	0	11.5	0	9.6	0
90-120	7.2	0	14.6	0	11.4	9.0
120-150	8.6	1.5	7.4	0	8.9	17.9
Am Sul + N-Serve						
0- 15	7.7	111.7	25.3	147.3	20.4	154.5
15- 30	32.1	9.4	45.3	64.7	10.2	1.0
30- 60	11.2	0	8.1	0	11.8	0
60- 90	4.8	0	6.1	0	11.2	0
90-120	4.1	0	9.2	0	10.5	16.3
120-150	3.3	0	6.5	3.4	7.9	2.9
Urea						
0- 15	132.3	7.3	151.4	94.8	115.0	194.0
15- 30	83.4	5.3	76.0	26.0	24.5	10.2
30- 60	23.6	0.9	12.9	0	4.0	0
60- 90	7.3	0	16.5	0	1.6	4.2
90-120	8.9	0	7.3	0	3.6	0
120-150	10.2	0.6	6.8	0	2.3	0
Urea + N-Serve						
0- 15	13.9	252.1	15.7	189.1	19.1	209.1
15- 30	9.3	17.8	35.0	35.8	12.1	5.1
30- 60	4.3	1.2	21.2	2.7	6.3	0
60- 90	6.3	1.5	7.1	0	7.2	0
90-120	3.1	1.7	5.2	3.5	9.2	8.5
120-150	2.9	5.6	4.2	0	8.1	2.2
SCU-20						
0- 15	39.6	43.3	36.7	58.6	34,9	53.8
15- 30	42.6	0.5	24.3	1.3	17.1	2.2
30- 60	7.6	0	10.2	0	10.0	0
60- 90	6.0	0	5.7	0	8.2	0
90-120	3.6	0	3.7	0	5.0	7.1
120-150	4.6	0	2.4	0	5.9	1.2
SCU-20 + N-Serve						
0- 15	6.5	250.8	5.8	95.0	10.6	72.6
15- 30	8.1	3.9	7.9	2.1	6.3	0.5
30- 60	4.8	0	6.3	0	2.4	1.6
60- 90	4.1	0.7	4.6	0	2.5	0

Table 21. (Continued)

	Time of application					
	October		November		December	
Depth	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm					
SCU-20 + N-Serve						
90-120	6.1	0.9	3.0	0	1.6	0
120-150	3.7	1.7	2.4	0	1.6	1.3
SCU-30						
0- 15	115.7	83.4	53.7	72.7	82.4	219.8
15- 30	144.1	2.0	41.6	0	29.1	2.5
30- 60	9.5	ND	17.4	0	7.5	14.8
60- 90	5.6	ND	6.2	0	3.6	0
90-120	5.8	ND	48.0	53.6	3.6	1.0
120-150	6.1	ND	4.2	10.2	2.5	0
SCU-30 + N-Serve						
0- 15	6.3	189.0	5.0	165.5	14.2	107.2
15- 30	18.3	9.6	8.8	3.9	11.5	0
30- 60	10.3	0	4.8	0	7.3	0
60- 90	6.0	0	5.0	0	4.9	1.6
90-120	9.4	0	5.4	0	6.2	0
120-150	8.5	0	5.3	0	4.4	0
Am Sul (deep)						
0- 15	4.3	3.0	44.9	5.5	39.9	88.2
15- 30	5.4	0.5	72.9	5.6	41.4	136.2
30- 60	6.7	1.5	39.1	0	6.5	0
60- 90	10.9	1.2	7.9	0	4.0	0
90-120	8.7	1.5	4.1	0	6.8	0
120-150	5.8	1.5	5.0	0	4.5	0
Am Sul + N-Serve (deep)						
0- 15	22.3	59.1	10.1	100.2	16.1	129.8
15- 30	20.8	59.1	5.5	65.2	15.5	46.8
30- 60	8.3	4.2	6.1	1.3	3.6	0
60- 90	4.3	0	6.3	0	3.4	0
90-120	2.9	0	6.5	1.1	2.8	0
120-150	2.7	0.7	4.1	0	2.1	0
Control						
0- 15			12.4	2.8		
15- 30			6.8	1.9		
30- 60			2.3	ND		
60- 90			2.0	ND		
90-120			1.3	ND		
120-150			1.4	ND		

TABLE 22. TOTAL OF THE NO_3-N AND NH_4-N IN 120-CM PROFILES OF HOUSTON BLACK CLAY ON MAY 29, 1974 AFTER APPLYING 134 KG-N/HA

Treatment*	Time of application Nov.	Dec.	Feb.	March	Sidedress†	Average
	----------	----------	----------	kg-N/ha	----------	----------
Am Sul	406	222	580	479	176	373
Am Sul + N-Serve	402	239	325	289	121	275
Urea	473	271	664	521	172	420
Urea + N-Serve	403	204	420	338	139	301
SCU-20	169	104	385	156	26	168
SCU-20 + N-Serve	278	56	174	185	93	157
SCU-30	479	289	473	256	164	332
SCU-30 + N-Serve	290	128	278	302	99	219
Am Sul (deep)	394	267	420	500	249	366
Am Sul + N-Serve (deep)	492	270	367	334	176	328
Average	379	205	408	336	141	294

* The inorganic N level in the control plots was 33 kg-N/ha

† The sidedress treatment had received only one-half (67 kg-N/ha) the prescribed amount of N at sampling.

The readily soluble forms exhibited the maximum amount of leaching followed by SCU-30, then SCU-20. An example of comparative amount of leaching can be seen in the March applied treatments. Plots treated with readily soluble forms averaged 7.1 ppm NO_3-N below the 60-cm depth. Sulfur-coated urea-30 and SCU-20 averaged 6.5 and 3.9 ppm NO_3-N, respectively.

Time of application had no significant effect on exchangeable N levels except in December applied treatments. December applications averaged 40%

less soluble N in the entire profile than the other application periods. When the December applied group was sampled in February, the results were very similar to those discussed above. It is interesting to compare amounts of exchangeable N present in the profiles in February to the amount present in May, for November and December times of application. In February, the November applied group contained 501 kg/ha exchangeable N. The following May this group contained 501 kg/ha exchangeable N. This is a decrease of 24%. The December applied treatments contained an average of only 239 kg/ha exchangeable N in February and 205 kg/ha exchangeable N in May. This is a decrease of 14%. Since N uptake by the crop accounted for sizeable portions of the exchangeable N loss in both instances, it appears only small amounts of the exchangeable N present in February was removed from the soil solution by means other than crop utilization. It appears the most favorable period for N losses would be prior to January and February. If application date is compared independent of N source, no noticeable differences in degree of leaching are obtained other than for the December application period (Table 22).

The data in Table 23 indicates more NO_3-N is present in the lower 60 cm of the profiles of the treatments which had received the latest application of N. For example, the average NO_3-N concentration in the 60-120 cm depth of the $(NH_4)_2SO_4$ treatment was 4.8 ppm when the N was applied in November, but was 9.6 ppm when the N was applied in March. This same trend was evident in most of the other treatments. It appears the reason for this was more total N in the profiles of the latter application dates which was subject to leaching. Much of the earlier applied N had leached through the lower depths by the May sampling date as evident by the higher concentrations present at these depths in January (Table 17).

Generally, N-Serve caused a decrease in exchangeable N present at sampling. If N-Serve is considered independent of time of application and N source, it is apparent a 23% decrease in exchangeable N occurred by the addition of N-Serve. If N-Serve is considered versus time of application, more explanatory results are obtained. In the readily soluble N treatments the percent decrease in exchangeable N caused by N-Serve in the November, December, February, and March application periods is 8, 10, 40, and 37, respectively. This demonstrates the earlier applications of N-Serve caused only small decreases in exchangeable N levels while the latter months of application the decrease became large. Some of the decrease may be due to the fact NH_4-N is immobilized more rapidly than NO_3-N (Jansson, 1958). It may also be due to NH_4-N volatilization. No real conclusion can be drawn on this observation from the collected data.

That N-Serve significantly decreased NO_3-N leaching is best exemplified in the readily soluble treatments (Table 23). The respective decreases in NO_3-N content at 60-120 cm caused by N-Serve in the November, December, February and March times of application are 29%, 23%, 69%, and 60%. Some of this decrease may be due to the corresponding decreases in exchangeable N content when N-Serve was added. However, even when this data is considered jointly, N-Serve effected a substantial decrease in leachability of the applied fertilizer.

TABLE 23. CONCENTRATION OF NO_3-N AND NH_4-N IN 120-CM PROFILES OF HOUSTON BLACK CLAY AFTER RECEIVING 134 KG-N/HA PRIOR TO SAMPLING ON MAY 29, 1974

Treatment and depth	Time of application							
	November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm							
Am Sul								
0 - 15	51.1	0	23.0	0.9	86.0	0	33.4	0.6
15 - 30	50.8	0	36.1	0	99.2	0	75.6	0
30 - 60	20.2	10.0	12.6	0	24.1	1.0	33.2	0
60 - 90	5.7	ND	4.7	ND	7.8	ND	13.1	ND
90 - 120	3.8	ND	2.1	ND	3.9	ND	6.0	ND
Am Sul + N-Serve								
0 - 15	65.2	26.0	37.1	4.6	52.2	34.6	25.6	75.1
15 - 30	39.8	3.6	31.7	0	35.4	0	30.1	17.8
30 - 60	16.1	0	10.2	0	7.2	0	9.0	2.4
60 - 90	4.5	ND	4.2	ND	2.8	ND	3.2	ND
90 - 120	1.8	ND	2.2	ND	1.5	ND	1.7	ND
Urea								
0 - 15	43.1	0	35.1	0	83.2	0	38.9	0
15 - 30	68.6	0	48.0	0	114.8	0	87.2	0
30 - 60	41.4	0	13.1	0	34.8	0	43.4	0.6
60 - 90	5.2	ND	4.2	ND	10.7	ND	6.1	ND
90 - 120	3.1	ND	2.7	ND	3.7	ND	3.2	ND
Urea + N-Serve								
0 - 15	58.2	8.2	42.2	15.6	65.1	73.1	32.8	44.1
15 - 30	46.5	0	15.4	0.6	31.5	0	40.3	0.8
30 - 60	27.0	0	4.7	0	5.3	0	10.1	0
60 - 90	4.9	ND	2.2	ND	2.0	ND	4.2	ND
90 - 120	1.4	ND	1.7	ND	1.6	ND	2.2	ND

Table 23. (Continued)

Treatment and depth	Time of application							
	November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm							
SCU-20								
0 - 15	13.4	18.3	5.2	0	77.9	46.0	11.6	2.2
15 - 30	14.2	2.1	9.3	0	14.1	0	16.9	3.9
30 - 60	7.6	0	9.9	0	9.8	0	9.6	0
60 - 90	4.1	ND	4.0	ND	4.3	ND	4.7	ND
90 - 120	2.2	ND	2.2	ND	2.8	ND	3.2	ND
SCU-20 + N-Serve								
0 - 15	24.0	64.3	7.7	1.4	6.6	53.2	2.8	42.2
15 - 30	10.1	0	3.0	0	3.1	0	6.0	9.5
30 - 60	6.8	0	3.4	0	3.7	0	5.1	0
60 - 90	3.9	ND	2.3	ND	2.4	ND	3.2	ND
90 - 120	2.0	ND	0.7	ND	1.4	ND	2.5	ND
SCU-30								
0 - 15	70.1	67.4	49.4	4.2	97.5	23.0	18.0	0
15 - 30	38.5	0.7	32.3	0	36.1	0	44.0	0
30 - 60	12.0	0	14.6	0	19.1	0	13.2	0
60 - 90	4.8	ND	5.4	ND	5.2	ND	7.2	ND
90 - 120	1.8	ND	1.7	ND	3.0	ND	5.9	ND
SCU-30 + N-Serve								
0 - 15	28.0	66.5	30.5	9.5	28.0	66.0	6.8	78.2
15 - 30	16.8	0	5.3	0	9.5	0	18.7	10.3
30 - 60	5.9	0	2.7	0.8	5.3	0	5.0	0
60 - 90	1.9	ND	1.6	ND	2.9	ND	3.5	ND
90 - 120	1.4	ND	0.7	ND	2.1	ND	1.9	ND

Table 23. (Continued)

Treatment and depth	Time of application							
	November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm							
Am Sul (deep)								
0 - 15	38.9	0	6.2	0	2.2	0	63.0	0
15 - 30	62.4	0	30.8	0	60.3	0	68.2	0
30 - 60	27.9	0	31.0	0	33.7	0	32.7	0
60 - 90	7.5	ND	7.0	ND	18.8	ND	8.7	ND
90 - 120	2.0	ND	2.9	ND	7.2	ND	4.6	ND
Am Sul + N-Serve								
0 - 15	77.1	13.9	20.6	6.2	8.5	1.5	36.4	25.6
15 - 30	63.4	0	41.9	2.9	40.2	57.4	36.0	19.2
30 - 60	24.9	0	15.9	0	20.4	0	5.7	0
60 - 90	5.5	ND	5.7	ND	5.0	ND	8.2	ND
90 - 120	2.2	ND	2.8	ND	2.7	ND	2.1	ND
			NO_3-N	NH_4-N				
Control								
0 - 15			1.5	1.5				
15 - 30			2.2	0				
30 - 60			1.8	0.1				
60 - 90			1.5	ND				
90 - 120			1.6	ND				

Houston Black Clay-1975--

During the second year of this study, fertilizer treatments were applied on October 18, November 19, and December 20, 1974, and on February 21 and March 25, 1975. A split application was made on March 25 (at planting) and May 19. The treated plots were sampled to a depth of 120 cm on June 6, 1975.

The total NO_3-N and NH_4-N found in the 120-cm profiles are listed in Table 24. The March applied treatments contained 35% more inorganic N than the October applied treatment. The November applied group was also considerably lower than the other times of application. If the amounts of exchangeable N present in the soil at the June 6 sampling period are compared to the amounts present at the January sampling period (Table 16), it is evident N loss or immobilization occurred after the earlier sampling date. In June, the October applied group contained 31% less (198 kg-N/ha) exchangeable N than was present in January (289 kg-N/ha). The November applications averaged 44% less. Those applied in December contained equal amounts of exchangeable N at both sampling dates. The decrease in soluble N concentrations in the soil from January to June can be attributed to diffusion out of the fertilizer band and sampling zone, immobilization by microorganisms, as well as denitrification, leaching and plant uptake. The fact there was no difference in N levels for the December treatment would tend to indicate the decrease in soluble N occurred soon after the January sampling date while the N in the December application treatment was mainly in the NH_4-N form (Table 16) and not as subject to the loss mechanisms mentioned above.

During the 1974 spring sampling, N-Serve caused a decrease in exchangeable N in almost all cases (Table 22). The data in Table 24 indicates N-Serve had no significant effect on exchangeable N levels. If N-Serve is considered independently of N source and time of application, versus total exchangeable N, the resulting values are 258 kg-N/ha exchangeable N for the N-Serve treatments and 259 kg-N/ha for the non-N-Serve treatments. The results are similar if time of application is included in this comparison. The differences obtained in 1974 were large and consistent. Because the observations of this sample period are not comparable to those of 1974, one may conclude that environmental factors seriously influenced the results.

Table 25 demonstrates the amount of NO_3-N that had moved to a depth of 60 to 120 cm in the profiles. Observing the data organized in this fashion gives a good indication of the amount of downward movement that had occurred during the various time intervals. When N-Serve is considered as a treatment independent of N source, it can be shown that the addition of N-Serve resulted in less NO_3-N leaching. Plots not treated with N-Serve contained an average 78 kg NO_3-N/ha in the 60-120 cm depth while N-Serve treated plots contained 34% less or 51 kg-N/ha. At this sampling period, the check plots contained only 11 kg/ha NO_3-N in the 60-120 cm depth.

The more soluble N sources (urea and $(NH_4)_2SO_4$) resulted in more NO_3-N leaching than the sulfur-coated ureas. The former sources averaged 59, 71, 72, 89, and 194 kg-N/ha below 60 cm, respectively, for the March, February, December, November, and October application periods. This indicates more leaching occurred the longer the fertilizers were in the soil. The maximum amount of leaching occurred with the October treatment while the least

TABLE 24. TOTAL NO_3-N AND NH_4-N IN 120-CM PROFILES OF HOUSTON BLACK CLAY ON JUNE 6, 1975 AFTER RECEIVING 134 KG-N/HA

Treatment	October		November		December		February		March		Average (sum)
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	
	--------------------------------				kg-N/ha					--------------------------------	
Am Sul	355	0	222	0	216	0	190	3	262	0	250
Am Sul + N-Serve	206	42	101	22	212	14	174	62	136	132	220
Urea	181	0	136	8	387	0	332	0	286	2	266
Urea + N-Serve	211	2	207	4	371	171	162	88	170	106	298
SCU-20	86	28	102	14	102	56	152	67	80	2	138
SCU-20 + N-Serve	125	10	87	32	92	40	84	24	61	70	125
SCU-30	174	16	137	23	180	0	162	55	337	76	232
SCU-30 + N-Serve	161	11	205	40	163	34	186	41	89	95	205
Am Sul (deep)	182	2	165	0	274	0	295	38	295	2	251
Am Sul + N-Serve (deep)	191	0	187	7	209	61	133	106	151	130	235
Average	187	11	155	15	221	38	187	48	187	61	222
			NO_3-N		NH_4-N						
Control			41.3		0						

TABLE 25. AMOUNT OF NO_3-N PRESENT BELOW 60 CM OF DEPTH IN 120-CM PROFILES OF HOUSTON BLACK CLAY THAT HAD RECEIVED 134 KG-N/HA PRIOR TO SAMPLING ON JUNE 6, 1975

	Time of application					
Treatment	Oct.	Nov.	Dec.	Feb.	March	Average
	kg-N/ha					
Am Sul	264	102	63	84	39	107
Am Sul + N-Serve	67	57	50	37	43	51
Urea	100	76	82	58	79	79
Urea + N-Serve	72	79	68	46	48	63
SCU-20	40	51	28	42	42	41
SCU-20 + N-Serve	41	46	39	38	38	40
SCU-30	78	73	52	49	78	66
SCU-30 + N-Serve	44	98	31	39	43	51
Am Sul (deep)	111	99	73	80	77	88
Am Sul + N-Serve (deep)	58	65	43	39	39	49
Average	90	75	53	51	53	64
Control	11					
No N-Serve	78					
N-Serve	51					

occurred in the March applied treatments. This data agrees well with that collected in 1974 during the same time interval.

In the SCU treatments, the amount of NO_3-N present below 60-cm was approximately equal for all months of application. The average amount was 50 kg NO_3-N/ha. This indicates the application of SCU resulted in about 34% less NO_3-N moving into the lower depths of the profile than for the more soluble N sources.

The relative amounts of NO_3-N and NH_4-N found in the profiles in June are listed in Table 26. The effect of N-Serve on the nitrification of fertilizer applied NH_4-N was substantial for a relatively long period of time. The percent of the inorganic N that was in the NH_4-N form was relatively constant for all treatments which did not receive N-Serve. In the non-N-Serve treated plots approximately 8% of the inorganic N present was NH_4-N regardless of the month applied. This indicates the fertilizer applied NH_4-N was nitrified rapidly in the absence of N-Serve. When N-Serve was applied the percent NH_4-N present was 47.8% for the March treatment, while the February, December, November, and October treatments contained 32.1%, 21.6%, 13.3%, and 6.3%, respectively. The NH_4-N content of the October treatment was essentially the same as the treatment without N-Serve. Ammonium N content differences began to appear in the November applied treatment and increased as the application date moved closer to the sampling date. This indicates N-Serve affected nitrification for at least 207 days, but less than 228 days.

A urea analysis was performed on all the sulfur-coated urea treated plots. The results of this data were erratic but do give an indication that a considerable amount of the SCU applied was still hydrolyzed and in the sulfur-coated prill at sampling time in June. The average urea content in the soil profiles of the October, November, and December applied treatments was 300 kg-N/ha. The February and March treatments averaged 353 kg-N/ha. The overall average for the SCU-20 treatment was 458 kg urea N/ha, while the SCU-30 treatments only contained 184 kg-N/ha. This signifies SCU-20 is much more insoluble than SCU-30 since the SCU-20 plots contained 2.4 times more urea-N.

Norwood Silt Loam-1974--

Fertilizer applications were made to preselected plots of Norwood silt loam on November 19, and December 17,1973, and on February 18, April 3, and a split application on April 3, and May 21, in 1974. The April applications were made at planting. On June 4, two soil cores were taken from each plot to a depth of 150 cm.

Exchangeable N levels (Table 27) were significantly affected by N source. When N source is considered independent of time of application, the N content of plots treated with readily soluble sources averaged 426 kg-N/ha. The SCU-30 source was similar with an average 415 kg-N/ha. The SCU-20 treatments were significantly lower with an average of only 280 kg-N/ha. This is approximately 30% less than the SCU-30. This data is similar to that obtained in the Houston Black clay during the same time interval. Both locations indicated the dissolution rate of SCU-30 increased substantially

TABLE 26. CONCENTRATIONS OF NO_3-N and NH_4-N IN 120-CM PROFILES OF HOUSTON BLACK CLAY ON JUNE 6, 1975, AFTER RECEIVING 134 KG-N/HA

Treatment and depth	Time of application									
	October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm									
Am Sul										
0 - 15	4.4	0	4.4	0	6.3	0	4.6	1.2	13.5	0
15 - 30	4.6	0	12.6	0	23.1	0	50.8	0	49.5	0
30 - 60	10.5	ND	17.4	0	23.7	0	30.5	0	18.9	0
60 - 90	37.3	ND	14.4	ND	9.9	ND	11.7	ND	8.5	ND
90 - 120	26.9	ND	10.3	ND	5.5	ND	8.7	ND	7.5	ND
Am Sul + N-Serve										
0 - 15	20.4	18.7	7.8	10.2	18.4	6.5	15.8	24.7	29.3	62.1
15 - 30	46.8	0	16.6	0	29.0	0	20.7	3.3	12.6	0
30 - 60	25.5	0	16.8	0	14.8	0	13.4	0.7	9.0	0
60 - 90	9.5	ND	7.9	ND	7.3	ND	4.5	ND	5.0	ND
90 - 120	6.8	ND	5.9	ND	4.9	ND	4.4	ND	5.4	ND
Urea										
0 - 15	3.6	0	4.9	3.7	21.4	0	8.5	0	8.8	0.3
15 - 30	20.3	0	5.9	0	48.3	0	70.3	0	46.5	0.7
30 - 60	7.5	0	9.0	0	38.0	0	28.2	0	21.9	0
60 - 90	12.9	ND	10.2	ND	13.1	ND	8.6	ND	12.0	ND
90 - 120	11.3	ND	8.2	ND	6.9	ND	5.6	ND	7.1	ND
Urea + N-Serve										
0 - 15	14.1	1.0	6.0	1.7	41.9	69.3	11.3	38.4	18.0	49.9
15 - 30	18.8	0	16.7	0	51.7	11.5	24.5	2.9	18.6	0
30 - 60	16.6	0	19.4	0	25.4	0	9.8	0	10.8	0
60 - 90	9.7	ND	11.0	ND	10.6	ND	4.9	ND	5.4	ND
90 - 120	7.9	ND	8.1	ND	5.9	ND	6.3	ND	6.2	ND

Table 26. (Continued).

Treatment and depth	Time of application									
	October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm									
SCU-20										
0 - 15	5.6	13.4	5.4	6.7	15.7	26.2	13.9	21.8	6.1	1.5
15 - 30	4.2	0	5.2	0	6.7	0	19.4	9.6	10.6	0
30 - 60	6.1	0	6.9	0	6.4	0	9.7	0	9.3	0
60 - 90	5.1	ND	6.3	ND	3.8	ND	5.3	ND	5.5	ND
90 - 120	4.6	ND	6.0	ND	3.1	ND	4.9	ND	4.7	ND
SCU-20 + N-Serve										
0 - 15	8.2	4.7	3.5	15.2	9.0	18.7	5.0	9.8	3.3	31.9
15 - 30	13.0	0	6.8	0	6.4	0	5.5	0	3.1	0
30 - 60	9.5	0	4.5	0	4.8	0	5.5	0.8	2.3	0.5
60 - 90	5.7	ND	5.3	ND	4.4	ND	4.7	ND	4.4	ND
90 - 120	4.3	ND	6.0	ND	5.2	ND	4.7	ND	4.7	ND
SCU-30										
0 - 15	5.8	7.4	9.2	10.8	5.1	0	96.7	25.8	40.5	36.1
15 - 30	8.0	0	3.7	0	19.4	0	12.2	0	33.2	0
30 - 60	16.2	0	8.7	0	18.4	0	1.0	0	24.9	0
60 - 90	9.4	ND	10.3	ND	7.1	ND	5.8	ND	10.2	ND
90 - 120	9.6	ND	7.6	ND	5.6	ND	6.2	ND	8.8	ND
SCU-30 + N-Serve										
0 - 15	13.5	10.1	7.9	19.1	26.0	13.0	10.1	18.2	5.8	44.2
15 - 30	17.4	0	10.3	0	19.0	0	21.1	1.1	7.8	0.5
30 - 60	12.7	0	16.5	0	8.8	1.5	19.7	0	4.2	0
60 - 90	5.8	ND	14.9	ND	4.3	ND	5.3	ND	4.7	ND
90 - 120	4.8	ND	8.9	ND	3.3	ND	4.2	ND	5.8	ND

Table 26. (Continued).

Treatment and depth	Time of application									
	October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm									
Am Sul (deep)										
0 - 15	5.9	1.0	3.5	0	4.0	0	3.4	17.9	9.2	0.8
15 - 30	3.4	0	4.8	0	34.2	0	34.4	0	37.9	0
30 - 60	12.5	0	11.9	0	29.0	0	32.8	0	31.3	0
60 - 90	15.7	ND	14.8	ND	10.2	ND	12.0	ND	10.3	ND
90 - 120	11.1	ND	9.2	ND	7.6	ND	7.4	ND	8.4	ND
Am Sul + N-Serve (deep)										
0 - 15	6.6	0	4.7	0.8	8.9	20.2	6.5	32.9	15.9	54.0
15 - 30	28.3	0	16.3	2.5	39.6	8.4	20.7	17.0	20.5	6.7
30 - 60	14.1	0	18.8	0	15.4	0	8.7	0	8.3	0.4
60 - 90	7.5	ND	9.1	ND	6.3	ND	4.6	ND	4.5	ND
90 - 120	6.6	ND	6.7	ND	4.1	ND	4.9	ND	5.0	ND
			NO_3-N	NH_4-N						
Control										
0 - 15			5.2	0						
15 - 30			4.2	0						
30 - 60			2.5	0						
60 - 90			1.6	ND						
90 - 120			1.1	ND						

TABLE 27. TOTAL OF THE NO_3-N AND NH_4-N IN 150-CM PROFILES OF NORWOOD SILT LOAM ON JUNE 4, 1974, AFTER BEING TREATED WITH 134 KG-N/HA

Treatment	Time of application				Average
	Nov.	Dec.	Feb.	April	
Am Sul	310	433	421	403	392
Am Sul + N-Serve	477	471	419	487	464
Urea	332	358	777	478	486
Urea + N-Serve	469	322	265	403	365
SCU-20	188	238	269	314	252
SCU-20 + N-Serve	403	401	282	149	309
SCU-30	229	353	488	362	358
SCU-30 + N-Serve	644	246	531	469	472
Am Sul (deep)	253	316	569	636	444
Am Sul + N-Serve (deep)	338	178	247	347	278
Average	397	332	405	405	399
Control					114

during the spring while SCU-20 was influenced only slightly by warmer temperatures.

Time of application did not markedly influence exchangeable N concentrations except in the December treatments. The December applied group, as has been the case in all previous samplings, contained less exchangeable N. For the June 4 sampling period, it contained an average of 21% less soluble N than the other application treatments. Since this type of relationship was present throughout this study, it is apparent there are some undesirable climatic conditions which made the application of N fertilizers in December undesirable.

If the influence of time of application on exchangeable N level is determined on individual N sources, the results are as follows. The exchangeable N levels resulting from the application of $(NH_4)_2SO_4$ or urea was influenced only slightly by time of application on the Norwood silt loam in 1974. When applied in November these treatments averaged 397 kg-N/ha which was only 10% less than the amount observed in the April applied group. The SCU-30 treatments acted similar to the above mentioned readily soluble forms.

N-Serve effect on exchangeable N level was erratic, depending on time of application. Generally, N-Serve did not influence the total amount of soluble N found in the profiles. However, when time of application is included in the N-Serve examination, the results are quite different. When N-Serve was applied with the N in November, a considerable higher amount of soluble N (36%) was found. When applied with the fertilizer at the December, February, and April application dates, no influence on the total amount of soluble N in the profiles was observed. The significant loss of N from the non-treated N sources applied in November may be attributed to 5.2 cm of rainfall which occurred within 10 days of application. The rains were light and over an extended period of time which could have created denitrifying conditions in the soil.

Table 28 lists the relative depths of NO_3-N and NH_4-N in the profiles of Norwood silt loam in 1974. The plots receiving a N application during the winter months (November and December) had a higher NO_3-N concentration in the lower depths of the profile than plots fertilized in the spring. This can be demonstrated by viewing the $(NH_4)_2SO_4$ treatments versus time of application. The average amounts of NO_3-N found in the 60-150 cm depths for the $(NH_4)_2SO_4$ treatment applied in November, December, February, and April were 7.8, 5.9, 4.6, and 2.7 ppm, respectively. When N-Serve was added, the respective NO_3-N contents at these lower depths were 4.4, 3.8, 3.5, and 12.2 ppm. The April treatment was excessively high (12.2 ppm) due to a very high NO_3-N level was much more reasonable. Nitrate N leaching from the applied fertilizer was found to be lower for the SCU's than for the more soluble $(NH_4)_2SO_4$ and urea.

When all the treatments applied were averaged, it was found that 88% of the inorganic N was in the NO_3-N form. The remaining 12% was NH_4-N. For those plots treated with N-Serve and for those treated without N-Serve, the fraction of the inorganic N that was in the NH_4-N form was 20% and 6%, respectively. When the effect of N-Serve was considered versus time of application, it was noted the percent NH_4-N in the November, December, February, and April application periods were 10.2%, 13.2%, 26.7%, and 56.7%, respectively. When N-Serve was not included in the treatment, there was no significant difference between the NH_4-N percentages indicating nitrification is rapid in Norwood silt loam.

Norwood Silt Loam-1975--

During the second year, the various N sources were band applied at 134 kg-N/ha on October 18, November 19, and December 20, 1974 and on February 21, and March 12, 1975. Also, a split application was made March 12, and May 21. Soil samples were taken to a depth of 150 cm on May 21, 1975.

The NO_3-N and NH_4-N concentrations throughout the treated profiles are listed in Table 29. Nitrate N leaching has occurred to some extent in all

TABLE 28. CONCENTRATIONS OF NO_3-N AND NH_4-N IN 150-CM PROFILES OF NORWOOD SILT LOAM AFTER RECEIVING 134 KG-N/HA PRIOR TO SAMPLING ON JUNE 4, 1974

Treatment and depth	Time of application							
	November		December		February		April	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm							
Am Sul								
0 - 15	17.1	2.3	73.7	3.2	66.7	4.3	59.0	0
15 - 30	45.7	3.6	68.4	1.3	76.2	2.8	105.0	0
30 - 60	14.5	0	15.5	0	15.5	2.1	5.4	0
60 - 90	9.5	ND	9.1	ND	3.1	ND	2.5	ND
90 - 120	8.6	ND	2.7	ND	4.4	ND	3.0	ND
120 - 150	7.2	ND	2.4	ND	0	ND	2.6	ND
Am Sul + N-Serve								
0 - 15	103.2	2.3	85.5	4.3	70.1	11.0	49.9	26.8
15 - 30	72.4	3.6	85.1	10.9	72.5	7.3	28.0	6.6
30 - 60	13.4	0	9.9	0	9.4	1.4	50.1	0
60 - 90	3.4	ND	3.2	ND	2.5	ND	3.7	ND
90 - 120	3.0	ND	3.0	ND	3.5	ND	3.5	ND
120 - 150	2.5	ND	2.7	ND	2.0	ND	3.7	ND
Urea								
0 - 15	67.9	5.5	68.7	0.3	234.2	3.5	98.7	2.0
15 - 30	31.0	3.3	47.2	1.8	77.4	4.0	84.1	1.5
30 - 60	11.9	0	9.6	0	10.4	1.2	10.0	0
60 - 90	6.0	ND	7.0	ND	4.4	ND	5.5	ND
90 - 120	4.1	ND	5.0	ND	4.4	ND	2.7	ND
120 - 150	3.2	ND	4.5	ND	4.1	ND	2.1	ND

Table 28. (Continued).

Treatment and depth	Time of application							
	November		December		February		April	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm							
Urea + N-Serve								
0 - 15	123.7	4.1	44.1	30.9	60.7	3.6	64.0	38.4
15 - 30	50.1	4.6	34.6	9.7	35.4	2.4	48.4	12.7
30 - 60	9.2	0	7.4	0	4.4	0.7	5.2	0
60 - 90	4.1	ND	4.0	ND	3.0	ND	2.9	ND
90 - 120	2.9	ND	3.2	ND	2.1	ND	2.9	ND
120 - 150	3.7	ND	2.2	ND	1.7	ND	2.7	ND
SCU-20								
0 - 15	45.7	2.3	29.2	2.5	41.7	5.3	61.4	22.4
15 - 30	24.6	0.4	30.2	8.1	31.6	1.5	39.7	1.2
30 - 60	6.1	1.0	5.4	0	6.4	2.0	3.1	0
60 - 90	3.5	ND	5.0	ND	5.4	ND	3.1	ND
90 - 120	3.0	ND	8.1	ND	5.5	ND	3.4	ND
120 - 150	2.2	ND	3.2	ND	4.9	ND	2.5	ND
SCU-20 + N-Serve								
0 - 15	88.2	15.1	97.0	19.8	60.1	21.5	8.2	21.7
15 - 30	53.1	2.4	38.9	2.3	20.6	3.5	12.5	2.8
30 - 60	5.5	1.2	7.5	0	5.1	0	4.1	0
60 - 90	4.5	ND	3.2	ND	3,7	ND	3.0	ND
90 - 120	2.0	ND	2.4	ND	3.2	ND	2.6	ND
120 - 150	2.9	ND	2.9	ND	2.1	ND	3.0	ND

Table 28. (Continued).

Treatment and depth	Time of application							
	November		December		February		April	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm							
SCU-30								
0 - 15	48.6	3.1	71.6	6.7	138.6	1.5	93.0	2.4
15 - 30	24.6	3.9	37.7	0.4	54.5	0	37.7	15.4
30 - 60	6.5	ND	12.4	0	11.4	0	3.0	0
60 - 90	4.6	ND	6.1	ND	2.6	ND	2.9	ND
90 - 120	3.2	ND	3.1	ND	2.6	ND	2.7	ND
120 - 150	0	ND	4.1	ND	1.6	ND	2.9	ND
SCU-30 + N-Serve								
0 - 15	212.1	24.4	30.9	6.7	163.0	7.8	37.2	103.5
15 - 30	36.6	1.6	38.6	5.5	42.5	4.8	14.5	27.2
30 - 60	5.1	1.9	8.5	0	7.0	1.0	3.9	0
60 - 90	3.2	ND	3.1	ND	3.2	ND	3.1	ND
90 - 120	2.4	ND	3.0	ND	3.1	ND	4.1	ND
120 - 150	2.4	ND	3.0	ND	2.4	ND	9.0	ND
Am Sul (deep)								
0 - 15	26.6	0.8	11.7	0.8	65.5	1.2	138.0	0
15 - 30	38.9	0	40.5	1.4	147.4	4.9	126.5	0
30 - 60	10.4	1.0	28.7	ND	17.0	0	3.9	0
60 - 90	7.1	ND	5.6	ND	3.2	ND	2.5	ND
90 - 120	5.4	ND	4.9	ND	2.4	ND	3.2	ND
120 - 150	3.5	ND	9.5	ND	2.5	ND	8.6	ND

Table 28. (Continued).

Treatment and depth	Time of application							
	November		December		February		April	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm							
Am Sul + N-Serve (deep)								
0 - 15	72.9	4.1	2.2	0	9.1	18.5	17.6	46.6
15 - 30	38.4	3.9	22.5	1.4	12.4	42.3	42.1	28.2
30 - 60	6.4	1.0	8.9	0	5.2	0	6.0	0
60 - 90	4.9	ND	11.5	ND	4.7	ND	3.1	ND
90 - 120	4.0	ND	4.4	ND	4.4	ND	3.5	ND
120 - 150	4.0	ND	5.0	ND	3.4	ND	2.5	ND
Control			NO_3-N	NH_4-N				
0 - 15			9.0	1.3				
15 - 30			6.5	1.3				
30 - 60			4.6	0.8				
60 - 90			3.5	ND				
90 - 120			5.0	ND				
120 - 150			4.4	ND				

TABLE 29. CONCENTRATIONS OF NO_3-N AND NH_4-N IN 150-CM PROFILES OF NORWOOD SILT LOAM ON MAY 21, 1975, AFTER RECEIVING 134 KG-N/HA.

Treatment and depth	Time of application									
	October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm									
Am Sul										
0 - 15	4.5	1.8	4.5	3.6	7.1	1.9	5.3	40.9	53.7	0
15 - 30	17.2	1.4	21.6	2.2	17.3	0	17.7	0	72.9	0
30 - 60	17.9	ND	8.0	ND	25.6	ND	16.3	ND	11.8	ND
60 - 90	18.6	ND	13.8	ND	16.4	ND	16.5	ND	12.1	ND
90 - 120	13.0	ND	10.7	ND	14.5	ND	12.6	ND	8.6	ND
120 - 150	10.5	ND	9.3	ND	6.5	ND	7.4	ND	9.9	ND
Am Sul + N-Serve										
0 - 15	36.2	4.3	18.9	4.6	61.8	9.4	16.1	43.4	13.4	35.2
15 - 30	17.9	0	40.5	9.2	20.8	0	31.7	36.2	19.7	14.9
30 - 60	8.5	ND	14.0	ND	9.3	ND	9.1	ND	21.2	ND
60 - 90	8.0	ND	8.5	ND	7.2	ND	9.4	ND	13.1	ND
90 - 120	7.5	ND	9.5	ND	6.1	ND	7.8	ND	10.3	ND
120 - 150	7.3	ND	10.4	ND	9.6	ND	6.1	ND	8.0	ND
Urea										
0 - 15	4.5	1.8	4.5	3.6	7.1	1.9	5.3	40.9	53.7	0
15 - 30	17.2	1.4	21.6	2.2	17.3	0	17.7	0	72.9	ND
30 - 60	17.9	ND	8.0	ND	25.6	ND	16.3	ND	11.8	ND
60 - 90	18.6	ND	13,8	ND	16.4	ND	16.5	ND	12.1	ND
90 - 120	13.0	ND	10.7	ND	14.5	ND	12.6	ND	8.6	ND
120 - 150	10.5	ND	9.3	ND	6.5	ND	7.4	ND	9.9	ND
Urea + N-Serve										
0 - 15	51.8	1.4	9.6	2.5	26.4	64.0	30.2	106.4	16.6	120.9
15 - 30	25.9	0	20.9	0	26.9	ND	23.5	100.0	25.4	7.4

Table 29. (Continued).

Treatment and depth	Time of application									
	October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm									
Urea + N-Serve (cont.)										
30 - 60	4.4	ND	12.6	ND	5.2	ND	12.3	ND	5.9	ND
60 - 90	8.3	ND	7.0	ND	6.1	ND	10.8	ND	4.8	ND
90 - 120	6.2	ND	10.1	ND	6.9	ND	29.2	ND	4.6	ND
120 - 150	5.9	ND	8.1	ND	8.0	ND	10.8	ND	3.1	ND
SCU-20										
0 - 15	27.0	2.7	10.9	0	45.5	44.4	29.9	11.7	6.6	6.1
15 - 30	15.4	1.7	10.9	0	20.4	0	12.4	0	5.5	0
30 - 60	8.6	ND	11.3	ND	10.8	ND	8.0	ND	3.8	ND
60 - 90	10.0	ND	10.0	ND	9.4	ND	5.8	ND	4.2	ND
90 - 120	6.4	ND	9.7	ND	7.4	ND	5.9	ND	4.2	ND
120 - 150	7.0	ND	6.7	ND	7.6	ND	7.6	ND	2.6	ND
SCU-20 + N-Serve										
0 - 15	27.5	7.0	32.2	41.5	14.8	16.9	33.9	31.1	12.6	131.7
15 - 30	11.2	0	11.0	0	5.2	2.3	12.0	20.1	12.3	4.1
30 - 60	5.0	ND	6.9	ND	2.6	ND	5.1	ND	5.7	ND
60 - 90	6.9	ND	5.4	ND	3.2	ND	4.0	ND	5.2	ND
90 - 120	6.0	ND	5.6	ND	5.9	ND	3.5	ND	5.9	ND
120 - 150	5.2	ND	4.3	ND	4.1	ND	4.1	ND	1.4	ND
SCU-30										
0 - 15	4.3	5.4	31.9	10.6	22.2	2.6	41.5	16.0	33.8	17.5
15 - 30	2.8	0.9	24.7	6.7	23.6	0.7	21.1	2.4	24.6	0
30 - 60	7.2	ND	9.9	ND	10.0	ND	8.6	ND	5.9	ND
60 - 90	11.1	ND	10.6	ND	8.1	ND	8.6	ND	9.8	ND
90 - 120	10.7	ND	9.0	ND	9.5	ND	8.1	ND	9.5	ND

Table 29. (Continued)

Treatment and depth	Time of application									
	October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm									
SCU-30 (cont.)										
120 - 150	7.9	ND	8.2	ND	4.8	ND	8.4	ND	9.4	ND
SCU-30 + N-Serve										
0 - 15	22.5	10.6	28.4	8.0	24.7	10.9	33.9	31.1	9.0	61.2
15 - 30	23.9	0.5	18.0	0	11.8	1.9	12.0	20.1	8.1	6.5
30 - 60	9.4	ND	9.0	ND	8.0	ND	5.1	ND	4.3	ND
60 - 90	7.8	ND	6.3	ND	7.4	ND	4.0	ND	7.4	ND
90 - 120	8.6	ND	9.1	ND	5.5	ND	3.5	ND	8.8	ND
120 - 150	4.6	ND	7.5	ND	6.5	ND	2.8	ND	9.9	ND
Am Sul (deep)										
0 - 15	2.4	1.1	3.4	1.5	7.5	4.4	42.3	8.2	30.0	0
15 - 30	2.3	0	6.8	0	34.6	0	38.3	0	13.6	0
30 - 60	3.6	ND	6.9	ND	24.3	ND	9.3	ND	11.9	ND
60 - 90	3.7	ND	7.9	ND	14.4	ND	5.3	ND	19.6	ND
90 - 120	3.4	ND	6.5	ND	15.2	ND	6.4	ND	8.0	ND
120 - 150	5.1	ND	9.0	ND	11.2	ND	6.7	ND	9.2	ND
Am Sul + N-Serve (deep)										
0 - 15	2.4	1.0	16.1	4.3	8.6	20.8	24.1	47.5	15.4	8.0
15 - 30	2.7	ND	18.9	7.4	15.9	24.1	17.8	28.8	9.2	7.9
30 - 60	3.7	ND	11.8	ND	12.2	ND	5.2	ND	8.3	ND
60 - 90	6.2	ND	12.1	ND	5.9	ND	3.3	ND	7.3	ND
90 - 120	7.8	ND	8.3	ND	6.4	ND	6.7	ND	6.0	ND
120 - 150	6.9	ND	1.5	ND	6.8	ND	6.0	ND	6.3	ND

Table 29. (Continued).

Treatment and depth	Time of application October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
cm	ppm									
Control			NO_3-N		NH_4-N					
0 - 15			6.6		0					
15 - 30			4.8		0					
30 - 60			4.8		ND					
60 - 90			3.6		ND					
90 - 120			3.3		ND					
120 - 150			3.0		ND					

treated plots. This is exemplified in Table 30 which lists the amount of NO_3-N present below 60 cm but above the sampling depth of 150 cm. The control plots in this experiment averaged 42 kg NO_3-N/ha between 60-150 cm. However, the overall average amount of NO_3-N between 60-150 cm in the treated plots was 99 kg-N/ha. This is more than two times greater than the amount present in the control plots.

Time of application seemed to have little effect on the amount of NO_3-N present at these lower depths. The October treated plots contained 96 kg NO_3-N/ha between 60-150 cm, while March treated plots contained 99 kg-N/ha. The effect of N-Serve on NO_3-N leaching is also apparent in Table 30. The non-N-Serve treated plots contained 87 kg NO_3-N/ha at this depth.

TABLE 30. AMOUNT OF NO_3-N PRESENT BELOW 60 CM OF DEPTH IN 150-CM PROFILE OF NORWOOD SILT LOAM ON MAY 21, 1975, THAT HAD RECEIVED 134 KG-N/HA.

	Time of application				
Treatment	Oct.	Nov.	Dec.	Feb.	March
	----------------kg-N/ha----------------				
Am Sul	173	139	154	150	126
Am Sul + N-Serve	94	117	94	96	129
Urea	95	104	81	104	131
Urea + N-Serve	85	104	86	209	52
SCU-20	96	109	101	80	45
SCU-20 + N-Serve	75	63	54	48	52
SCU-30	123	115	92	104	118
SCU-30 + N-Serve	87	94	80	42	108
Am Sul (deep)	50	96	168	76	152
Am Sul + N-Serve (deep)	86	90	79	66	81
Average	96	103	99	97	99
Control	42				
No N-Serve	112				
N-Serve	87				

The slow release sources maintained a lower concentration of NO_3-N below 60 cm than the more soluble forms of N. Profiles treated with the soluble N forms contained 109 kg NO_3-N/ha while the SCU's contained 34% less or 72 kg-N/ha.

The data in Table 31 depicts total NO_3-N and NH_4-N remaining in the 150-cm profiles of Norwood silt loam on May 21, 1975. The average amounts of soluble N of all treatments applied in October, November, December, February, and March were 210, 243, 274, 355, and 319 kg-N/ha, respectively. The October treatments contained 65% of the amount present in the March treatment.

Effect of N-Serve on nitrification rate of fertilizer applied NH_4-N can be demonstrated by comparing relative amounts of NH_4-N and NO_3-N present in the profiles. Six percent of the exchangeable N was in NH_4-N on May 21 for the non-N-Serve treated plots, regardless of application date. This indicates nitrification was very rapid in this soil. In the N-Serve treated plots, the percent of the exchangeable N present that was in the NH_4-N form was 4.8, 12.1, 23.7, 44.7, and 43.6, respectively, for the October, November, December, February, and March treatments. This indicates there was some effect from N-Serve even in the November treatments which were applied 195 days prior to sampling.

Crop Response

Grain Yield in 1974--

Houston Black clay--Grain sorghum yields were not effected by additions of N. Generally, on the Blacklands soils of Texas, maximum response to N by grain sorghum is obtained when it is grown on the same land the previous year. Oats were the previous crop grown on the plot area used in this study. The lack of adequate rainfall in June and July also limited response to N applications and were responsible for low yields (Table 32). A poor stand of plants was obtained for the plots treated with $(NH_4)_2SO_4$. The reason for the lack of germination is not known. Soil NH_4-N levels, which are known to affect germination, were not unusually high in soil samples taken on February 6 (Table 18). Germination was affected even when the N was applied in November.

The plots treated with N-Serve or receiving SCU as the source of N tended to have slightly higher yields, but the increase was not significant.

Norwood silt loam--Grain yields were limited in 1974 due to the late season drought period. Rainfall during June and July was only 6.0 cm. There was a 45-day period during these two months when only 1.1 cm of rainfall fell as light showers.

No response to N applications was distinguishable (Table 33). Even though a difference in soil N was determined for the various N sources and times of application grain sorghum did not respond to these differences. Close observation of the data in Table 33 indicates the plots treated with N-Serve or SCU produced more grain than those receiving the readily soluble sources. However, plots which received no N also produced more grain than

TABLE 31. CONCENTRATION OF NO_3-N and NH_4-N IN 150-CM PROFILES OF NORWOOD SILT LOAM ON MAY 21, 1975, AFTER RECEIVING 134 KG-N/HA

Treatment	Time of application									
	October		November		December		February		March	
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
	kg-N/ha									
Am Sul	293	7	228	12	303	4	266	87	443	0
Am Sul + N-Serve	244	9	301	29	308	20	235	169	287	106
Urea	199	3	221	5	117	4	257	6	262	3
Urea + N-Serve	267	3	220	5	221	136	374	438	166	272
SCU-20	222	9	201	0	285	94	202	25	87	13
SCU-20 + N-Serve	177	15	183	88	107	41	166	108	128	288
SCU-30	167	7	275	37	230	7	271	39	266	37
SCU-30 + N-Serve	224	24	230	17	190	27	161	109	192	144
Am Sul (deep)	92	2	135	3	357	9	285	17	293	0
Am Sul + N-Serve (deep)	112	2	213	25	181	95	176	162	167	34
Average	210		243		274		355		319	
Control			NO_3-N 85		NH_4-N 0					

TABLE 32. GRAIN SORGHUM YIELDS IN 1974 ON HOUSTON BLACK CLAY FERTILIZED WITH 134 KG-N/HA OF VARIOUS N SOURCES

	Time of application					
Treatment	Nov.	Dec.	Feb.	March	Side-dress	Average
	--------	--------	--------	kg/ha	--------	--------
Am Sul	3377	2496	1891	2697	3060	2704
Am Sul + N-Serve	3197	3619	2881	2984	3497	3232
Urea	3362	4166	2088	3144	3258	3204
Urea + N-Serve	3724	3353	3278	2675	2710	3148
SCU-20	3362	3352	3441	2371	3217	3149
SCU-20 + N-Serve	3417	3428	3440	3056	3295	3327
SCU-30	3832	2766	3076	2930	3025	3126
SCU-30 + N-Serve	3344	3447	3473	2308	2869	3088
Am Sul (deep)	----	3007	3123	2498	2593	2805
Am Sul + N-Serve (deep)	3119	3650	3017	2264	3674	3145
Average	3413	3328	2970	2693	3120	3525
Control	3139	3445	3119	2792	3152	3129

those receiving the readily available N sources. None of the yield differences were significant.

Nitrogen Uptake in 1974--

Houston Black clay--The concentration of N in the plant tissue was affected by N application on the Houston Black clay even though grain yields were not affected. The grain sorghum which did not receive any N fertilizer averaged 1.86% N, whereas, those plants which were fertilized averaged 2.34%. There was no difference in plant uptake of N between plots treated with readily soluble forms of N, but they contained more N than the sulfur-coated urea treated plants. The average N content in the plants fertilized with the soluble forms of N was 2.43% as compared to 2.23 % for the SCU fertilized plant (Table 34).

TABLE 33. GRAIN SORGHUM YIELDS IN 1974 ON NORWOOD SILT LOAM FERTILIZED WITH 134 KG/HA OF VARIOUS N SOURCES

Treatment	Time of application Nov.	Dec.	Feb.	March	Side-dress	Average
	----------------	----------------	kg/ha	----------------	----------------	----------------
Am Sul	3793	1940	1938	3037	2902	2722
Am Sul + N-Serve	3573	3151	2582	2656	2136	2820
Urea	2871	1575	2574	2386	2370	2355
Urea + N-Serve	2447	2866	3266	2023	2054	2731
SCU-20	5303	2565	3017	2828	2659	3274
SCU-20 + N-Serve	2882	2083	2690	2874	3174	2741
SCU-30	2863	3818	3143	3036	2899	3152
SCU-30 + N-Serve	3144	2994	2656	2456	2684	2781
Am Sul (deep)	2636	2285	2587	2835	2785	2626
Am Sul + N-Serve (deep)	2699	1351	3929	3135	3413	2905
Average	3221	2463	2838	2774	2808	2811
Control	4285	2432	3009	3091	3441	3252

Application time had no effect on N uptake. The sidedress application which appears to contain less N, had received only one-half as much N as the other application treatments.

Norwood silt loam--Nitrogen application influenced the concentration of N in the plant tissue of the plants grown on the Norwood silt loam even though it did not affect grain yields. As shown in Table 35, there was essentially no difference in protein content of the grain sorghum between sources or times of application. The only difference was when no N was applied. Average protein N of sorghum which did not receive N was 1.96%, whereas, those receiving 134 kg-N/ha was 2.30%. Plant samples were taken on June 7, 1974. This was the pre-boot stage and prior to the drought period which occurred in June and July. Sampling prior to the drought may explain why there was a difference in N content between the grain sorghum receiving

TABLE 34. PROTEIN N IN GRAIN SORGHUM PLANTS ON MAY 22, 1974, GROWING ON HOUSTON BLACK CLAY FERTILIZED WITH 134 KG-N/HA AT VARIOUS TIMES

Treatment	Nov.	Dec.	Feb.	March	Sidedress
	Time of application				
	--------------------% N----------------------				
Am Sul	2.45	2.54	2.42	2.48	2.39
Am Sul + N-Serve	2.47	2.34	2.42	2.42	2.30
Urea	2.61	2.46	2.43	2.41	2.30
Urea + N-Serve	2.37	2.37	2.41	2.44	2.83
SCU-20	2.39	2.15	2.37	2.21	2.12
SCU-20 + N-Serve	2.19	2.33	2.14	2.37	2.06
SCU-30	2.35	2.46	2.23	2.18	2.06
SCU-30 + N-Serve	2.32	1.98	2.17	2.28	2.28
Am Sul (deep)	2.41	2.18	2.58	2.43	2.46
Am Sul + N-Serve (deep)	2.42	2.50	2.47	2.41	2.50
Average	2.40	2.33	2.36	2.36	2.33
Control	1.91	1.94	1.74	1,91	1.82

an application and the control plots, but no difference in grain yields nor in protein content of the harvested grain.

Grain Yield in 1975--

Houston Black clay--The average grain yield for the 1975 season on the Houston Black clay pots was 3,336 kg/ha. There was a significant difference (0.05% level) only at the December time of application, the average yield of all treatments applied in October, November, December, February, March, and sidedress were 3,436, 3,394, 2,990, 3,487, 3,469, and 3,577 kg/ha, respectively (Table 36). The average yields are similar regardless of time of application. This data agrees with the soil data which indicated December treatments were always lower in exchangeable N.

There was also a significant treatment effect. The N-Serve treated sources were all significantly greater than the control, while the non-N-Serve

TABLE 35. PROTEIN N IN GRAIN SORGHUM PLANTS ON JUNE 7, 1974, GROWING ON NORWOOD SILT LOAM FERTILIZED WITH 134 KG-N/HA AT VARIOUS TIMES

	Time of application				
Treatment	Nov.	Dec.	Feb.	March	Sidedress
	--------------------% N----------------------				
Am Sul	2.14	2.54	2.42	2.48	2.39
Am Sul + N-Serve	2.86	2.34	2.50	2.42	2.30
Urea	2.66	2.46	2.40	2.41	2.33
Urea + N-Serve	2.35	2.37	2.41	2.44	2.33
SCU-20	2.40	2.15	2.32	2.22	2.12
SCU-20 + N-Serve	2.77	2.33	2.00	2.37	2.06
SCU-30	2.55	2.46	2.35	2.18	2.06
SCU-30 + N-Serve	2.46	1.98	2.17	2.28	2.28
Am Sul (deep)	2.32	2.18	2.58	2.43	2.46
Am Sul + N-Serve (deep)	2.29	2.50	2.47	2.41	2.50
Average	2.48	2.33	2.36	2.36	2.27
Control	2.39	1.94	1.74	1.91	1.83

treatments were not. It is interesting that every N source applied exhibited an increase in grain yield when treated with N-Serve. The SCU-20 + N-Serve treatment exhibited the greatest yield with $(NH_4)_2SO_4$ + N-Serve following with the second highest yield.

Norwood silt loam--Grain yields were not affected by the addition of N (Table 37). No significant difference was obtained among the treatments or the times of application.

Nitrogen Uptake in 1975--

Plant tissue and grain samples were collected at both locations for crude protein analysis. The soil data indicated the exchangeable N level on most treatments were more than sufficient to maintain a normal level of N in

TABLE 36. GRAIN SORGHUM YIELDS IN 1975 ON HOUSTON BLACK CLAY FERTILIZED WITH 134 KG-N/HA OF VARIOUS N SOURCES.

Treatment	Time of application Oct.	Nov.	Dec.	Feb.	March	Sidedress	Average
	--------------------	--------------------	----------	kg-N/ha	--------------------	--------------------	----------
Am Sul	3676	3029	1841	3152	3169	3901	3128
Am Sul + N-Serve	2681	3546	3746	3698	3659	3788	3521
Urea	3524	3040	1987	3265	3732	3450	3166
Urea + N-Serve	3450	3586	2944	3282	3642	3923	3471
SCU-20	3355	3490	3394	3563	3715	3507	2363
SCU-20 + N-Serve	3529	3507	3754	4053	3563	3845	3709
SCU-30	3299	3152	2910	3529	3619	3619	3355
SCU-30 + N-Serve	3659	3563	3169	3828	3248	3980	3575
Am Sul (deep)	3698	2854	2775	3304	3192	3265	3181
Am Sul + N-Serve (deep)	3490	3676	3377	3192	3152	2437	3221
Average	3436	3344	2991	3487	3469	3572	3269
Control	2629	2437	2854	3000	2702	2831	3269

TABLE 37. GRAIN SORGHUM YIELDS IN 1975 ON NORWOOD SILT LOAM FERTILIZED WITH 134 KG-N/HA OF VARIOUS N SOURCES

	Time of application						
Treatment	Oct.	Nov.	Dec.	Feb.	March	Sidedress	Average
	kg-N/ha						
Am Sul	2631	1826	1753	1357	1464	1118	1692
Am Sul + N-Serve	1919	2041	2214	1537	1622	1775	1851
Urea	1880	1768	2072	1600	1010	2326	1776
Urea + N-Serve	1936	1647	1933	1730	1389	1640	1713
SCU-20	2527	2170	2385	1630	1073	1831	1936
SCU-20 + N-Serve	1956	1662	2104	1986	1607	1704	1837
SCU-30	1834	1910	1643	1144	1670	1780	1664
SCU-30 + N-Serve	2137	1730	1892	1564	1620	1872	1803
Am Sul (deep)	1930	1273	2047	2047	1481	2148	1821
Am Sul + N-Serve (deep)	1544	2199	1683	2156	1891	2159	1939
Average	2029	1823	1973	1675	1483	1835	1939
Control	1430	1941	1651	1545	2197	1581	1803

the plant. Therefore, before extensive efforts were initiated to analyze all treatments, a selected group was examined to determine if there was any reasonable difference among treatments. Sixty samples were analyzed from each research location. It was concluded the only significant differences in protein content in the tissue samples were between the control and treated plots. No significant response was obtained in the grain protein data. Therefore, the remainder of the samples was abandoned.

SECTION 7

NITROGEN APPLICATIONS TO A GRASSLAND WATERSHED

A 7.7 ha (19.1 ac) grassland watershed was selected to study the fate of nitrogen applied to a typical watershed. The site was located on the Blacklands Experimental Watershed at Riesel, Texas, in Falls County. The soil was Houston Black clay and the site has an established sod of Coastal bermudagrass. Nitrate concentrations were determined in runoff waters, water wells within the watershed and in soil samples taken in the watershed. Uptake of nitrogen by bermudagrass was also determined.

PROCEDURE

In August of 1973, four shallow wells were installed down to and into semi-permeable C-horizon of the soil. The wells were installed by digging a trench approximately 75-cm in width and 2.5 m in length and about 30-cm into the C-horizon. A slotted 10-cm diameter PVC pipe was placed vertically in the trench. The trench was then back-filled with about 45-cm of 15-mm pea gravel and then covered with the original soil. The depth of the wells varied from 1.8 to 2.5 m depending on the depth to the C-horizon. Water samples were collected from the wells by manual sampling.

A Chickasha sediment sampler (Miller, et al., 1969) was constructed and installed at a weir already present in the watershed runoff channel. The sampler was designed to automatically collect water samples at various prescribed times during runoff flow. The sampler was installed during December of 1973.

Volume and rate of runoff flow were determined utilizing a water stage recorder. Nitrate levels in the water samples collected were determined by the phenoldisulfonic acid method. Records of when water samples were taken were recorded on the water stage recorder so that amounts of nitrate losses could be calculated from volume of flow data.

Five forage cages 1.5 m in diameter were installed on the watershed to determine forage production. A 0.8 m^2 area was harvested from each cage to estimate the forage production on the watershed and to determine nitrogen uptake. Cattle were allowed to graze the remainder of the watershed. Protein nitrogen was determined in the harvested forage by Kjeldahl distillation.

Soil samples were collected periodically to a depth of 150-cm using a power driven soil corer. Nitrates and ammonium were determined in the soil by the phenoldisulfonic acid method and by distillation, respectively.

The watershed was managed similar to methods used by farmers in the area. Fertilizer was surface applied twice each year at a rate of 90 kg-N/ha using NH_4NO_3. In 1974, the fertilizer was applied on March 5 and Septemeber 27. In 1975, the fertilizer was applied on March 16 and May 7.

RESULTS

Rainfall during the spring and early summer of 1974 at the 7.7 ha watershed at Riesel was much below normal. The total rainfall from January through July was only 29.3 cm. However, rainfall during the later part of August through November was exceedingly heavy (Table 38). The total rainfall received at the watershed site for 1974 was 103 cm.

Ninety kilograms per hectare of nitrogen as NH_4NO_3 was broadcast on the solid surface of the watershed on March 5 and again on September 27 in 1974.

Nitrates in Runoff Water During 1974

Ten major runoff producing storms occurred during 1974. Several runoff events occurred during the early part of the year, but the majority of the runoff occurred in late summer and during the fall. Several runoff events were not of sufficient magnitude to activate the sampler, and on at least two occasions the sampler malfunctioned and did not collect any samples. The first runoff samples were collected on February 21, prior to fertilization. Nitrate concentrations in the runoff water were low with no levels above 0.7 ppm NO_3-N occurring (Table 39). The total amount of runoff was 0.80 cm and the total NO_3-N lost was only 0.027 kg/ha (Table 40). The second runoff producing storm occurred 39 days after applying the 90 kg/ha of nitrogen. Nitrate-nitrogen concentration in the runoff water from the April 13 storm was much higher than in the earlier runoff. Concentrations of NO_3-N as high as 7.2 ppm were measured. The highest concentrations of nitrate in the runoff water occurred in the 7th sample collected. The first water collected contained the lowest level of nitrate and the concentration increased until the peak concentration was reached and then started to decrease when runoff flow ceased after the 9th sample collected, at which time concentration of NO_3-N in the runoff water was 4.2 ppm. The total runoff was 1.02 cm and the total amount of NO_3-N lost in the runoff water was only 0.42 kg/ha. The average concentration in the runoff water during the entire event was 3.9 ppm NO_3-N. Rainfall during the summer was not sufficient to cause any major runoff events. Twenty runoff samples were collected from the second runoff event in September. The concentration of NO_3-N in the runoff was essentially nil (Table 39). The total amount of nitrogen lost from the watershed in the runoff was only 0.030 kg/ha.

Fertilizer was again applied to the watershed on September 27 when the water content of the soil was near field capacity. A runoff producing storm did not occur until the last of October, although 1.72 and 0.38 cm of rainfall had occurred on October 4 and October 24, respectively (Table 38). The concentration of NO_3-N in the runoff water following the September application of nitrogen was appreciably higher than in the runoff water preceeding the application. However, the highest concentration found in any of the samples collected was only 2.3 ppm (Table 39). The total amount of nitrogen

TABLE 38. DAILY RAINFALL ON GRASSLAND WATERSHED AT RIESEL, TEXAS IN 1974

Day	Jan.	Feb.	March	April	May	June
			----cm----			
1.	0.02				3.00	
2.						
3.	0.10				0.05	
4.						
5.					2.12	
6.	0.02					
7.	0.02					
8.	0.02					
9.	0.02		0.05			0.60
10.	0.58		0.80		0.43	
11.				2.48		
12.			0.22			0.60
13.	0.10			2.85		
14.		0.25	0.75			
15.						
16.						
17.						
18.	0.88	0.32				
19.						
20.			1.08			
21.		1.93				
22.						
23.	0.63					
24.	0.83		0.60			
25.	1.03					
26.	0.72					
27.				1.15		
28.						
29.				0.28		
30.				0.72		
31.						
Monthly Totals	4.97	2.50	3.50	7.48	5.60	1.20

TABLE 38. (Continued)

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
			cm			
1.						
2.					0.02	
3.		0.28	1.70			
4.				1.72	0.70	
5.						0.42
6.						
7.		0.82			1.83	
8.					0.05	
9.			0.90		0.17	
10.			2.48		1.20	
11.	0.12					
12.			1.42			
13.			3.18			
14.	0.53		0.90			
15.	0.20					
16.	1.35		2.38			
17.			10.22			
18.						
19.						
20.						
21.			0.40			
22.		3.85				
23.					8.12	
24.			0.08	0.38	0.62	0.52
25.		0.32	0.25			
26.	0.95	5.10	0.08			0.55
27.		0.25				
28.		2.13		1.35		0.10
29.		1.55			0.90	0.10
30.		2.18		3.45		0.10
31.	0.95			8.92		0.30
Monthly Totals	4.10	16.48	23.99	15.82	13.61	3.77
Yearly Total			103.02			

TABLE 39. CONCENTRATION OF NO_3-N IN RUNOFF WATER FROM GRASSLAND WATERSHED AT RIESEL, TEXAS IN 1974

Sample No.	Feb. 21 1974	March* 13 1974	Sept. 3 1974	Sept. 17 1974	Oct.* 30 1974	Nov. 23 1974
	ppm NO_3-N					
1	0.7	1.8	0	0.1	1.6	0.5
2	0.3	2.2		0	2.2	0.3
3	0.3	2.8		0.1	2.2	0.3
4	0.3	3.4		0	2.3	0.3
5	0.3	4.6		0	0.5	0.2
6	0.1	7.0		0	0.3	0.3
7	0.3	7.2		0	0.3	0.3
8	0.3	7.0		-	0.2	0.2
9		4.2		-	0.2	0.2
10				-	0.2	0.3
11				-	0.2	0.2
12				-	0.2	0.2
13				-	0.3	0.2
14				-	0.1	0.1
15				0.1	0	0.2
16				0	0.2	0.3
17				0	0.2	0.2
18				0	0.1	0.1
19				0.1		0.2
20				0	0.2	
21				1.0		
22				0.2		
23				0		
24				0		
25				0		
26				0		
27				0		

* 90 kg/ha of nitrogen as NH_4NO_3 was applied on March 5 and September 27, 1974

TABLE 40. TOTAL RUNOFF AND NITROGEN LOST IN RUNOFF FROM 7.7-HA GRASSLAND WATERSHED IN 1974

Date of Runoff	Runoff (cm)	Nitrogen lost (kg/ha)
January 18 - 29	1.52	-----
February 21 - 23	0.80	0.027
March 20 - 22 *	0.05	-----
April 13 - 14	1.08	0.424
May 1 - 2	1.00	-----
May 5 - 7	0.50	-----
September 10 - 15	2.08	-----
September 16 - 19	10.00	0.030
October 30 - November 2 *	6.58	0.301
November 4 - 13	1.42	0.001
November 23 - 27	5.15	0.125
November 29 - 30	0.05	-----
December 5 - 15	0.88	-----
December 24 - 31	0.02	-----
Totals	31.13	0.908

* Nitrogen at the rate of 90 kg/ha was applied on March 5 and September 27, 1974

removed from the watershed by the 6.6-cm runoff was only 0.30 kg/ha.

Subsequent runoff events during the fall of 1974 removed very little nitrogen from the watershed and the concentrations in the runoff water were very low.

The total amount of runoff in 1974 was 31.1 cm and the amount of NO_3-N lost from the watershed was somewhat over 0.9 kg/ha. The total amount of nitrogen lost in the runoff could not be estimated exactly due to malfunctions of the sampling equipment on several occasions. However, it is estimated that less than 1.0 kg/ha of nitrogen was lost from the watershed in 1974. This is about 0.5% of the nitrogen applied to the watershed. The average concentration of NO_3-N in the runoff water for the entire year would be 0.3 ppm if it is assumed that 1.0 kg/ha of NO_3-N was lost from the watershed in 1974.

Nitrates in Runoff Water During 1975

Rainfall recorded during 1975 at the grassland watershed is given in Table 41. The total recorded is slightly below average for the area while the monthly distribution was relatively normal throughout the year. During

TABLE 41. DAILY RAINFALL ON GRASSLAND WATERSHED AT RIESEL, TEXAS IN 1975

Day	Jan.	Feb.	March	April	May	June
			cm			
1.		0.62				
2.		5.30				
3.		1.12	0.28			
4.					0.22	
5.						
6.						
7.				0.52		
8.				0.72		
9.	0.60		0.35	0.30		0.32
10.						0.38
11.	1.25				0.48	
12.	0.55					
13.			2.25	0.65	0.10	
14.					0.80	
15.					0.30	
16.			0.35			
17.		0.70	0.55			
18.						
19.					0.82	
20.					1.60	
21.						
22.						
23.		0.30			5.68	
24.					3.08	
25.						0.48
26.						5.52
27.						2.15
28.				1.75	1.55	1.68
29.				2.38	2.62	
30.						0.22
31.						
Monthly Totals	2.40	8.04	3.78	6.32	17.25	10.75

TABLE 41. (Continued)

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
			cm			
1.	0.22	1.45				
2.		1.10			3.18	
3.		0.45				
4.						0.25
5.						
6.						
7.			0.12			
8.			0.08			
9.		0.30	2.08			
10.	0.					
11.						
12.	0.50					
13.						
14.						
15.			0.38			
16.			2.08			
17.						
18.						
19.					0.45	
20.			1.70			
21.			0.38			
22.	0.38	0.48		1.08		
23.				1.10		
24.				0.90		
25.				1.90		
26.						3.40
27.		0.72				
28.						
29.	0.38					
30.					0.92	
31.						
Monthly Totals	1.48	4.50	6.82	4.98	4.55	3.65
Yearly Total			74.52			

May and June this watershed received the largest rains for single storms and overall totals for the month. These occurred after two applications of nitrogen had been made. Nitrogen was applied as ammonium nitrate at the rate of 90 kg-N/ha on March 16 and May 7, 1975.

During 1975 there were ten runoff producing storms (Table 42). Runoff samples were collected from four of these events. The sampling equipment malfunctioned on two of the events and the other four events produced insufficient runoff to sample. The storms from which samples were collected occurred on February 2, May 24, May 29, and June 28. The nitrate-nitrogen concentrations found in water samples taken during these storms are given in Table 43. The storm on February 2, occurred more than a month prior to the first nitrogen application. Nitrate nitrogen was 0.4 ppm in the first sample with each successive sample containing a lower concentration. There were no significant runoff producing storms between the first and second nitrogen applications. The next runoff storms were recorded on May 24 and 29. This was 17 and 22 days, respectively, after the second nitrogen application. Due to sampler malfunction 16 samples were not collected from the runoff produced by the storm on May 24. Although 1.1 and 1.0 ppm nitrate nitrogen were recorded in the first two samples, this is much lower than that recorded during the April storm in 1974. The concentrations in the samples taken during the May 29 and June 28 storms were only slightly higher than in the runoff from the February storm and were similar to the concentrations found in 1974 which occurred prior to fertilizer application. These samples which were lost could have been higher in nitrates than the first two samples since this was the case in the previous year during a similar storm. However, this is somewhat unlikely since there occurred 6 days of light to moderate showers (Table 41) totaling 4.1 cm of rainfall between the time of last application and the runoff producing storm of May 24. This amount of rainfall would probably be sufficient to leach the nitrates several centimeters into the soil and thereby prevent appreciable losses in the runoff waters. In addition, favorable growing conditions probably resulted in considerable plant uptake of the fertilizer nitrogen. Due to extremely dry conditions during the last half of the year no runoff was recorded. The total amount of nitrogen lost due to runoff storms was 6.46 kg/ha. This amounted to only 3.6% of the fertilizer applied.

Nitrates in Shallow Water Wells During 1974

Nitrate concentration in the four shallow wells located within the grassland watershed indicated that some leaching of applied nitrogen was occurring. Table 44 gives the levels of NO_3-N in the wells at various times during 1974. Only Well 1 contained water throughout the year. Wells 2, 3, and 4 contained water only after heavy rains or during extended wet periods during the fall and winter. As previously indicated, nitrogen fertilizer was applied on March 5 and September 27.

Nitrate levels in the well waters prior to fertilizer application were relatively low. Well 2 had a somewhat higher concentration ranging from 1.0 to 2.1 ppm NO_3-N. However, following nitrogen application, the concentrations in Well 2 increased to 61 ppm NO_3-N after the first rainfall which caused percolation into the wells on April 1. The nitrate level did not increase

TABLE 42. TOTAL RUNOFF AND NITROGEN LOST IN RUNOFF FROM 7.7-HA GRASSLAND WATERSHED IN 1975

Date of Runoff	Runoff (cm)	Nitrogen lost (kg/ha)
January 1 - 5	0.38	----
January 9 - 19	0.98	----
February 1 - 8	5.12	1.21
March 13 - 14	1.15	----
March 17 - 20 *	0.02	----
April 28 - 30 *	0.10	----
May 23 - 24	4.72	2.67
May 28 - 29	1.90	1.58
June 27 - 29	1.02	1.00
December 24 - 26	0.18	----
Totals	15.57	6.46

* Nitrogen fertilizer was applied at the rate of 90 kg/ha on March 16 and May 7, 1975

significantly in Well 1 on the April 1 sampling date. Rainfall in March and April was not sufficient to cause percolation into all wells, as demonstrated by the lack of water in Wells 3 and 4. The lack of rainfall could explain the low concentration of NO_3-N in Well 1 and the high concentration in Well 2. Well 1 always contained a considerable amount of water. If a small amount of nitrate and water leached into the purged water table in Well 1, it would be diluted and the concentration in the well water would not change significantly. However, if the same amount of nitrate and water leached into Well 2, the result would be a high nitrate concentration. This was probably the case for Well 2 which was dry in March and had a high NO_3-N concentration on April 1.

Over 5 cm of rainfall fell during the first week of May causing additional percolation. The NO_3-N concentration in Well 1 increased significantly to 9.7 ppm, whereas the concentration in Well 2 was diluted to 20 ppm by May 7. On this date Well 3 contained some water but the concentration of nitrates was below 1 ppm.

The concentration in Well 1 dropped to zero by June 1 and remained very low throughout the summer. The other wells were dry throughout the summer. Well 2 contained some water on September 6 following heavy rains and had a concentration of 16.5 ppm NO_3-N. Well 1 contained 2.3 ppm at this time.

Fertilizer nitrogen was applied again on September 27. Only 1.72 cm of rainfall fell from September 27 until October 23. This caused no appreciable

TABLE 43. CONCENTRATION OF NO_3-N IN RUNOFF WATER FROM 7.7-HA GRASSLAND WATERSHED IN RIESEL, TEXAS IN 1975

Sample No.	Feb. 2 1975	May 24 1975	May 29 1975	June 28 1975
	ppm NO_3-N			
1	0.4	1.1	0.4	0.4
2	0.3	1.0	---	0.4
3	0.3	0.1	0.5	0.4
4	0.3	- - -Sampler Malfunction- - -	0.3	0.4
5	0.3		0.4	0.3
6	0.2		0.4	0.4
7	0.3		0.5	0.4
8	0.3		0.7	
9	0.3		0.5	
10	0.3		0.5	
11	0.1		0.5	
12	0.2		0.5	
13	0.3		0.5	
14	0.1		0.4	
15	0.2		0.5	
16	0.1		0.3	
17	0.1		0.5	
18	0.1		0.5	
19	0.2		0.5	
20	0.1	0.4	0.5	
21	0.1	0.4	0.4	
22	0.1	0.2	0.4	
23	0.1	0.2	0.4	
24	0.1	0.4	0.4	
25	0.1		0.5	
26	0.1			
27	0.1			

percolation of water. From October 23 until the next sampling date on November 8, 7.7 cm of rainfall fell. The concentration of NO_3-N in all four wells was significant, ranging from 2.8 ppm in Well 4 to 22.6 ppm in Well 3. Heavy rains occurred again on November 23 and 24 which caused the nitrate levels in the wells to decrease appreciably. However, the concentration were considerably higher in November and December of 1974 as compared to concentrations in the spring of 1974 prior to fertilizer application.

TABLE 44. CONCENTRATION OF NO_3-N IN SHALLOW WELLS IN 7.7-HA GRASSLAND WATERSHED AT RIESEL, TEXAS IN 1974

Date	Well			
	1	2	3	4
	ppm NO_3-N			
October 16, 1973	0.1	1.0	0.2	0.2
March 5, 1974	---	2.1	0.3	d
April 1, 1974 *	0.5	61.0	d	d
May 7, 1974	9.7	20.0	0.2	d
June 1, 1974	0.0	d	d	d
June 20, 1974	0.1	d	d	d
September 6, 1974	2.3	16.5	d	d
September 13, 1974	0.4	d	d	d
November 8, 1974	14.4	18.8	22.6	2.8
November 20, 1974	6.0	d	d	d
November 27, 1974	4.5	5.4	d	d
December 13, 1974	2.8	6.2	7.1	1.6

* 90 kg/ha of nitrogen as NH_4NO_3 was applied on March 5 and September 27, 1974

d well was dry

Nitrates in Shallow Water Wells During 1975

The concentrations of NO_3-N in the shallow wells on January 2, 1975 were rather high (Table 45). Samples collected in December of 1974 also contained rather high concentration of NO_3-N (Table 44). This indicates that the nitrogen which was applied in September of 1974 was still affecting the water in the wells and that enough rainfall had not occurred to dilute the nitrates in the water. Well 1 which contained water throughout 1974 contained only 1.7 ppm as compared to 12 ppm in Well 3. It is evident that the nitrates leached into Well 1 were diluted by the larger quantity of water present in this well.

The concentrations in Wells 1 and 4 decreased to almost negligible levels by February 5. This was caused by 9.5 cm of rainfall which occurred since the previous sampling date. The concentrations in Wells 2 and 3 decreased about threefold during the same period, but still contained 2.7 and 3.4 ppm N, respectively. The NO_3-N levels remained low until the first of May which corresponded to the first appreciable rainfall (Table 41) following the initial application of nitrogen in 1975. On May 1, NO_3-N concentrations in the wells had increased to levels ranging from 5.7 to 11.2 ppm. On June 11 and July 3, concentrations of 33 and 20.5 ppm NO_3-N, respectively, were recorded in samples taken from Well 1. These values are extremely high and

TABLE 45. CONCENTRATION OF NO_3-N IN SHALLOW WELLS IN GRASSLAND WATERSHED AT RIESEL, TEXAS IN 1975

Date	Well 1	Well 2	Well 3	Well 4
	ppm NO_3-N			
January 2, 1975	1.7	8.0	12.0	1.3
February 5, 1975	0.3	2.7	3.4	0.1
February 25, 1975	0.0	d	d	1.2
February 27, 1975	0.2	2.8	d	1.8
March 16, 1975 *	0.6	3.8	d	1.0
April 14, 1975	0.8	d	d	d
May 1, 1975	6.0	11.2	9.9	5.7
May 7, 1975 *	5.3	d	d	d
May 27, 1975	6.0	10.2	11.2	3.7
June 11, 1975	33.0	d	d	0.4
July 3, 1975	20.5	d	d	0.2
July 28, 1975	4.0	d	d	d

* 90 kg/ha of nitrogen was applied as NH_4NO_3 on March 16 and May 7, 1975
d well was dry

show the potential hazard which could occur in this soil after nitrogen applications. It is possible that these rains were adequate to produce leaching, but not large enough to cause appreciable dilution. Well 1 consistently contained more water than any of the other wells, and in fact, contained water throughout the year. It seems possible that Well 1 could have collected water from a larger area of the watershed thus accumulating a high concentration of nitrates when conditions were ideal. It is apparent that duration and intensity of each storm causes different amounts of leaching of nitrates depending on time and previous weather and soil conditions. Due to the dry conditions during the last half of 1975, rainfall was inadequate to induce leaching.

Nitrogen Uptake by Forage

Forage production on the watershed was limited in 1974 due to the lack of rainfall during much of the growing season. Only 23-cm of rainfall fell on the watershed from March 1 through August 21. Very little forage was produced during the summer months as indicated in Table 46. The average total forage yield from 3 harvests was 2584 kg/ha. The amount of nitrogen taken up by the forage was only 27.3 kg/ha. This is only 30.5% of the 90 kg/ha of the nitrogen applied.

TABLE 46. YIELD OF COASTAL BERMUDAGRASS AND N UPTAKE IN SPRING AND SUMMER OF 1974 FOLLOWING SPRING APPLICATION OF 90 KG-N/HA TO WATERSHED

	Harvest Date							
	April 7 1974		June 20 1974		September 6 1974		Total	
Plot	Yield	N Uptake	Yield	N Uptake	Yield	N Uptake	Yield	N Uptake
	kg/ha							
1	1609	11.4	493	4.5	559	5.4	2661	21.3
2	----	----	775	8.1	483	6.6	1258	14.7
3	2200	25.1	644	6.6	601	6.2	3446	37.9
4	1431	19.0	407	4.4	271	3.4	2109	26.8
5	1160	12.2	575	6.2	385	4.8	2120	23.2
Ave.	1600	17.0	578	5.9	460	5.3	2638	28.2

TABLE 47. YIELD OF COASTAL BERMUDAGRASS AND N UPTAKE IN FALL OF 1974 FOLLOWING FALL APPLICATION OF 90 KG-N/HA TO WATERSHED

November 20, 1974 - Sampling Date

Plot	Yield kg/ha	Protein % N	N Uptake kg/ha
1	721	2.34	16.9
2	1057	1.56	16.5
3	1176	1.65	19.4
4	932	1.78	16.6
5	1583	1.51	23.9
Ave.	1094	1.70	18.7

The yield of forage from the fall application of N was only 1094 kg/ha (Table 47) with a nitrogen uptake of only 18.6 kg/ha. This represents an uptake efficiencey of only 20.8%.

Four clippings of forage were taken at monthly intervals from the watershed in 1975 (Table 48). The average total yield was 5968 kg/ha of Coastal bermudagrass with 116 kg/ha of nitrogen utilized as protein over the entire growing season. The first two clippings were after nitrogen had been applied at the rate of 90 kg/ha. Nevertheless, these applications did not seem to promote significant growth over that observed in the check pasture adjoining this watershed. However, there was a visual difference in color. The Coastal bermudagrass was noticeably greener where nitrogen had been applied. Data for the first three harvests indicates a small yield. Each harvest should have yielded over 3000 kg/ha of forage under good growing conditions; however, due to the small amount of rainfall and poor nitrogen utilization in the first two growing periods, this potential was not obtained.

On a total basis more than 116 kg of nitrogen should have been recovered as protein nitrogen in the Coastal bermudagrass. Since 180 kg of nitrogen was applied per hectare, the 116 kg only represents a 65% recovery not counting native nitrogen available in the soil profile.

Nitrates and Ammonium in Soil Profiles

Very little nitrogen was found in the soil profiles except for the top 30-cm of soil when sampled soon after nitrogen application. No ammonium was found in the soil following the spring application of ammonium nitrate. However, an average 25.8 kg/ha of nitrate-nitrogen was found in the top 30 cm of soil 17 days after the application of 90 kg/ha of nitrogen (Table 49). Very little inorganic nitrogen was found in the soil on May 7 and June 20. Essentially all the nitrogen found in the soil on March 22 was either utilized by the growing bermudagrass or immobilized in the soil. It is unlikely that any significant amount of nitrogen leached through the soil since only 16.2 cm of rainfall fell from the time of nitrogen application until the soil samples of May 7 were taken. However, Table 44 indicates that some nitrogen had leached into the shallow wells, and the soil samples taken on March 22 indicate that some nitrogen had moved down to 45-60 cm.

An appreciable amount of ammonium was found in the top 30-cm of soil following the fall application of nitrogen. The ammonium persisted for at least 55 days following application (Table 49). Nitrate concentrations were also very high in the top 15 cm of soil on October 17, three weeks after application. However, only 1.7 cm of rainfall had fallen since the date of application. The dry soil surface in the upper part of the soil profile probably prevented the uptake of nitrogen from the upper 15 cm of soil. The nitrate indicated to be present from 60-120-cm was found in only 1 of 5 profiles sampled. Four profiles had no detectable levels of nitrate.

Rainfall between October 17 and the next sampling date on November 20 amounted to 18 cm. Considerable percolation of water occurred during the first week in November. All four of the shallow observation wells contained water on November 8. The well water also contained considerable amounts of

TABLE 48. YIELD OF COASTAL BERMUDAGRASS AND N UPTAKE IN SPRING AND SUMMER OF 1975 FOLLOWING APPLICATIONS OF 90 KG-N/HA TO WATERSHED

Plot	Harvest Date in 1975									
	May 7		June 17		July 29		September 8		Total	
	Yield	N-Uptake	Yield	N-Uptake	Yield	N-Uptake	Yield	N-Uptake	Yield	N-Uptake
	----------	----------	----------	----------	kg/ha	----------	----------	----------	----------	----------
1	1611	37.3	1583	32.7	1599	16.4	802	9.7	5583	95.5
2	1735	44.0	2244	51.9	1816	23.4	792	10.2	6586	129.5
3	1859	43.9	1382	32.5	2060	29.7	911	12.0	6211	118.0
4	1718	45.6	2098	51.9	1805	28.1	661	9.7	6282	135.3
5	1138	27.8	1903	40.9	1643	22.8	846	11.5	5529	103.0
Ave.	1612	39.8	1842	41.9	1784	24.1	802	10.6	6005	116.5

TABLE 49. SOIL PROFILE NITROGEN IN WATERSHED AT VARIOUS TIMES AFTER APPLYING 90 KG-N/HA AS NH_4NO_3 ON MARCH 5 AND ON SEPTEMBER 27, 1974

	Dates Sampled in 1974									
	March 22 *		May 7		June 20		Oct. 17 *		Nov. 20	
Depth (cm)	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
	kg/ha									
0- 15	0.0	19.4	0.0	4.7	0.0	1.1	7.2	36.3	16.5	2.4
15- 30	1.8	6.4	0.0	1.6	0.0	0.4	4.3	0.2	6.3	1.1
30- 45	0.0	3.8	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.4
45- 60	0.0	3.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.4
60- 75	0.0	1.2	0.0	0.1	0.0	0.0	0.0	2.2	0.0	0.4
75- 90	0.0	0.3	0.0	0.2	0.0	0.0	0.0	2.2	0.0	1.1
90-105	0.0	0.2	0.0	0.4	0.0	0.0	0.0	2.4	0.0	1.1
105-120	---	---	---	---	0.0	0.0	0.0	2.4	0.0	0.4
Total	0.8	34.7	0.0	7.9	0.0	1.5	11.5	45.7	22.8	7.3

* 90 kg/ha of nitrogen as NH_4NO_3 was applied on March 5 and September 27.

nitrates (Table 44). The soil samples taken on November 20 (Table 49) also indicate that some movement of nitrates had occurred since the last sampling. Four of the five profiles samples contained some nitrate down to 120 cm. About 34 kg/ha of NO_3-N was removed from the soil profiles between sampling dates. Plant uptake of N was only 18.6 kg/ha (Table 46). Nitrogen in runoff water during this period was less than 0.6 kg/ha. The 15.0 kg/ha of nitrogen was not necessarily lost by leaching. Immobilization was probably a major factor attributing to the disappearance of nitrate between October 17 and November 20.

Soil profile data gives some insight as to what might have happened to some of the nitrogen applied the previous year. Soil samples taken in February of 1975 (Table 50) show an insignificant amount of nitrogen carried over in the profile from the previous year. This agrees with the low amount of nitrogen found in the wells during February and March of 1975 (Table 45).

TABLE 50. SOIL PROFILE NITROGEN IN SAMPLES TAKEN AT VARIOUS TIMES FROM WATERSHED DURING 1975

	Dates Sampled in 1975					
	Feb. 25		May 1		May 27	
Depth (cm)	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N
	kg/ha					
0- 15	5.6	0.9	11.8	3.9	15.2	5.8
15- 30	0.0	0.3	0.0	2.1	0.0	11.2
30- 60	0.0	0.3	0.0	2.8	0.0	2.0
60- 90	0.0	0.0	0.0	30.0	0.0	0.2
90-120	0.0	0.0	0.0	0.0	0.0	0.2
120-150	0.0	0.0	0.0	0.0	0.0	0.0
150-180	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.6	1.5	11.8	38.8	15.2	19.6

The high NH_4 and NO_3 levels found in the samples taken on May 1 were probably due to the March nitrogen application and to some native nitrogen production due to mineralization. The high nitrate value recorded in the 60- to 90-cm sample was due to a high concentration found in only one of the three samples taken. This could indicate a possible accumulation zone where one of the cores was taken. The sample with the high NO_3 concentration was taken from the top of the C horizon which in this soil is predominantaly semipermeable caliche. This sampling date corresponds with the date when high concentrations of NO_3-N were found in the well samples (Table 45).

The May 27 samples contained a similar amount of ammonium and nitrate as that found in the May 1 samples. However, no samples contained large concentrations of either nitrogen form to indicate accumulation. The soil cores do indicate some leaching of nitrates through the soil profile.

SECTION 8

FIELD LYSIMETERS

To determine the quantity of nitrates which leaches through the soil from different sources of nitrogen, five fertilizer treatments were applied to five lysimeters. Nitrate movement through the soil was determined by measuring NO_3-N in the soil profile and in the drainage effluent. Nitrogen uptake from the various treatments by grain sorghum was also determined.

PROCEDURE

Five "natural" drainage lysimeters were installed in Norwood silt loam near College Station, Texas, to determine the extent of nitrate movement through the soil from various sources of nitrogen. The lysimeters were constructed by welding two 1.2 x 2.4 m and two 1.2 x 1.2 m steel plates together to form a rectangular box with the top and bottom open. The inside dimensions of the boxes were 105-cm wide, 225-cm long and 120-cm deep. The boxes were placed on top of the soil where they were to be installed and concrete weights slowly placed on the boxes until they started moving into the soil. As the boxes moved into the soil, the soil around the outside wells was excavated with a backhoe and shovels to reduce the friction between the soil and the walls. Weight was added until the lysimeters had been pushed to a depth of 120 cm and the top edge of the walls were about 3 cm from the soil surface. The weights were then moved.

An excavation was then made on one side of the lysimeter in order to push the bottom of the lysimeter in place. A steel guide frame was made which was used to guide the bottom plate of the lysimeter while it was pushed into place. A 0.625-cm steel plate 1.2 x 2.4 m was placed on the guide frame in the excavation next to the lysimeter. Two 10 ton hydraulic jacks were used to push the steel plate under the lysimeter. After pushing the bottom plate, the space between the walls of the lysimeter and the bottom plate ranged from 0 to 3 cm. In order to seal the bottom to the lysimeter walls a steel strap was welded around the walls at the bottom of the lysimeter and to the bottom plate.

An underground room was constructed on one side of the lysimeters to collect drainage samples and make redox readings at different depths. The rooms were 1.2 x 2.4 m and 1.5 m high and made of cinder blocks. The top of the room which was made of 0.615-cm steel plate was 30 cm below the soil surface.

To install the drainage ports, 2-cm holes were drilled along the bottom of one side of the lysimeter 30 cm apart. A soil probe 1.25 cm in diameter was used to pull a soil core the entire width of the lysimeter. Drainage tubes, consisting of 1.25-cm porous cylindrical tubes cemented over slotted 9 mm stainless steel tubes 120-cm long, were inserted into the core holes along the bottom of the lysimeters through the drilled holes. The ends of the stainless steel tubes were passed through rubber stoppers which were inserted into the drilled holes in the side of the lysimeters to prevent leakage around the drainage ports. The drainage ports were connected by means of Tygon tubing and tension of 10 cm of water was maintained on the drainage tubes by means of a vacuum system connected to glass collection bottles.

Areas the same size as the lysimeters were established adjacent to the lysimeters to serve as duplicates and to allow for the collection of soil samples. Each lysimeter and its duplicate size area was located in the center of a plot 6.75 m wide and 7.5 m long. These plot areas were treated similar to the lysimeters.

The fertilizer treatments applied to each lysimeter in 1974 and 1975 are shown in Table 51. The treatments were applied at the rate of 168 kg-N/ha or 41 gms per lysimeter in both years. The fertilizer was applied at planting. Placement of the fertilizer was approximatly 7 cm below and 5 cm to the side of the seed. Grain sorghum (Sorghum vulgare) was planted in 25-cm rows in both 1974 and 1975. At maturity, grain and forage was harvested, weighed, and analyzed for nitrogen. After collecting a forage subsample for analysis, the remaining litter was returned to the soil.

Rainfall measurements were taken at a nearby weather station.

RESULTS

Grain Sorghum Yields

Grain sorghum yields and N-contents are given in Table 52. Yields from the lysimeters and the duplicate adjacent areas were used to determine statistical relationships between treatments. There was a considerable amount of variability between the lysimeter and their duplicate adjacent plots. There was no significant difference in yields between treatments within years. However, the grain yields in 1974 were significantly greater than the yields in 1975. In 1975, there was also a significant difference in %N in the forage between treatments. However, there was no significance between any grain yield or forage yield in 1974.

Nitrate Leaching

Leaching of nitrate through the lysimeter from the various sources of nitrogen fertilizers is shown in Figures 12-16. Very little NO_3-N was found in the effluents in 1974. Only the $Ca(NO_3)_2$ treatment (Fig. 15) resulted in significant NO_3-N concentrations in the effluents in 1974. The highest NO_3-N concentration in 1974 was only 0.68 ppm in November, seven months after the application of $Ca(NO_3)_2$. Generally, the concentrations were less than 0.5 ppm and the largest amount leached through any of the lysimeters was 123-mg from lysimeter 2 which was fertilized with NH_4Cl. However, the majority of this

TABLE 51. FERTILIZER TREATMENTS APPLIED TO FIELD LYSIMETERS

Lysimeter	Fertilizer treatments 1974	Fertilizer treatments 1975
I	NH_4Cl	NH_4Cl + 1% N-Serve
II	NH_4Cl	NH_4Cl
III	NH_4Cl + N-Serve	NH_4Cl
IV	$Ca(NO_3)_2$	$Ca(NO_3)_2$
V	SCU-20	SCU-20

TABLE 52. YIELD AND NITROGEN CONTENT OF GRAIN FROM LYSIMETERS

Lysimeter	Yield (kg/ha) Grain	Yield (kg/ha) Forage	N-content (%) Grain	N-content (%) Forage
	1974			
I	4842	*	1.78	0.64
II	4183	*	1.64	0.75
III	4990	*	1.78	0.78
IV	4509	*	1.53	1.02
V	4444	*	1.59	0.48
	1975			
I	3023	7084	1.25	0.93
II	2779	4642	1.17	0.81
III	2726	3459	1.10	1.05
IV	2769	6279	1.09	0.81
V	2367	5844	1.05	0.76

* Forage yield not determined

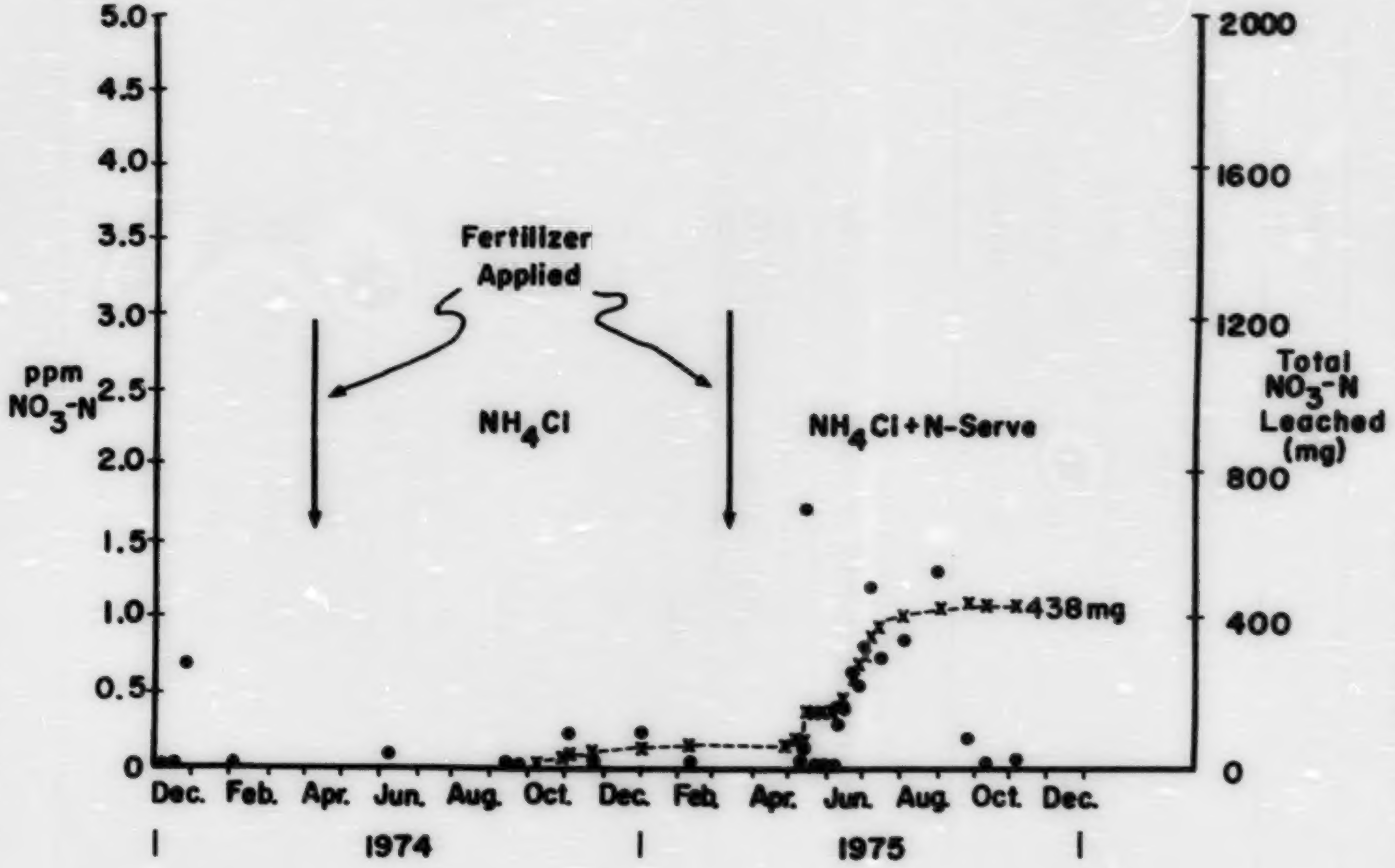

Figure 12. Concentration and cumulative NO_3-N found in drainage from Lysimeter 1 during 1974 and 1975 and fertilized with NH_4Cl and NH_4Cl treated with N-Serve.

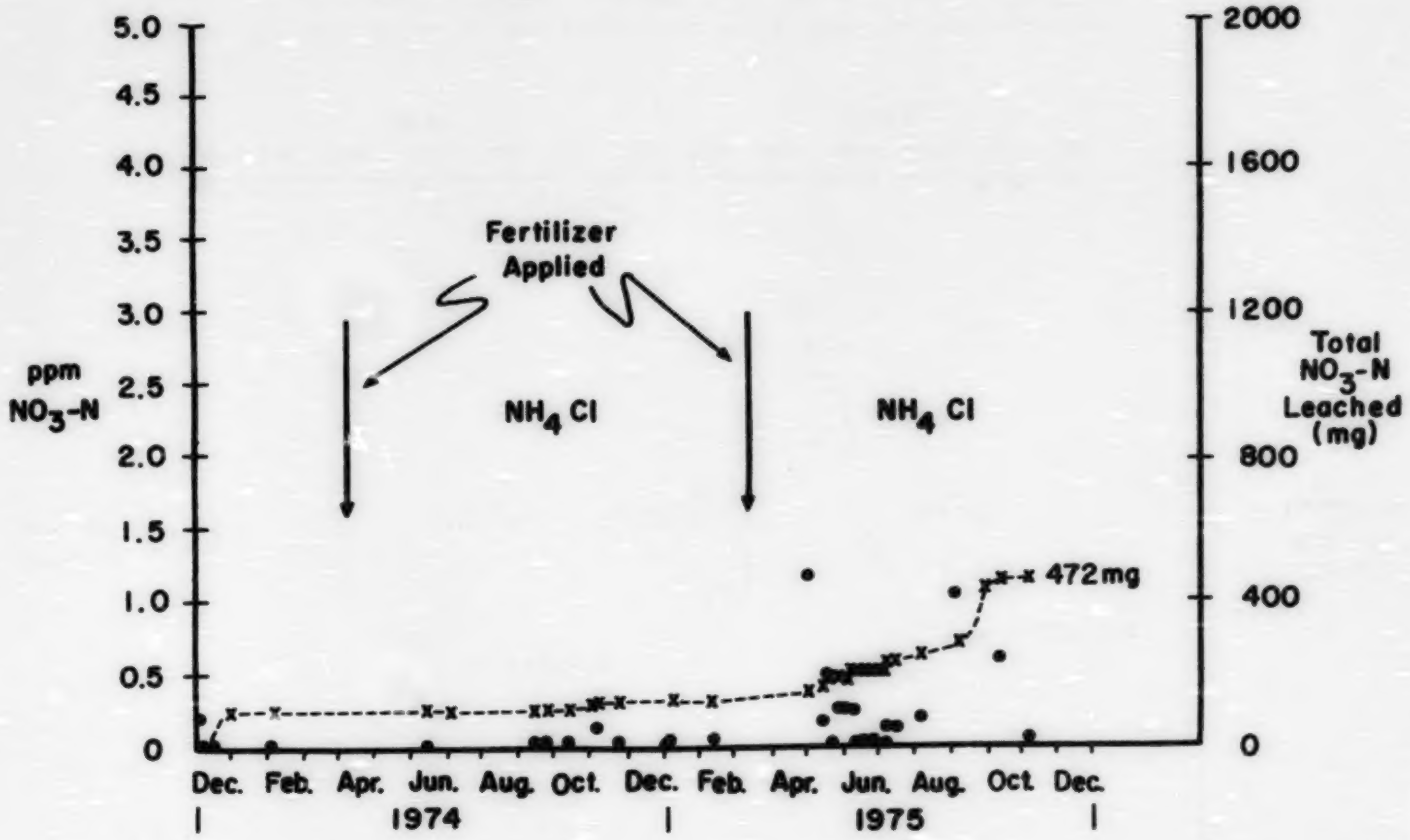

Figure 13. Concentration and cumulative NO_3-N found in drainage from Lysimeter 2 during 1974 and 1975 and fertilized with NH_4Cl.

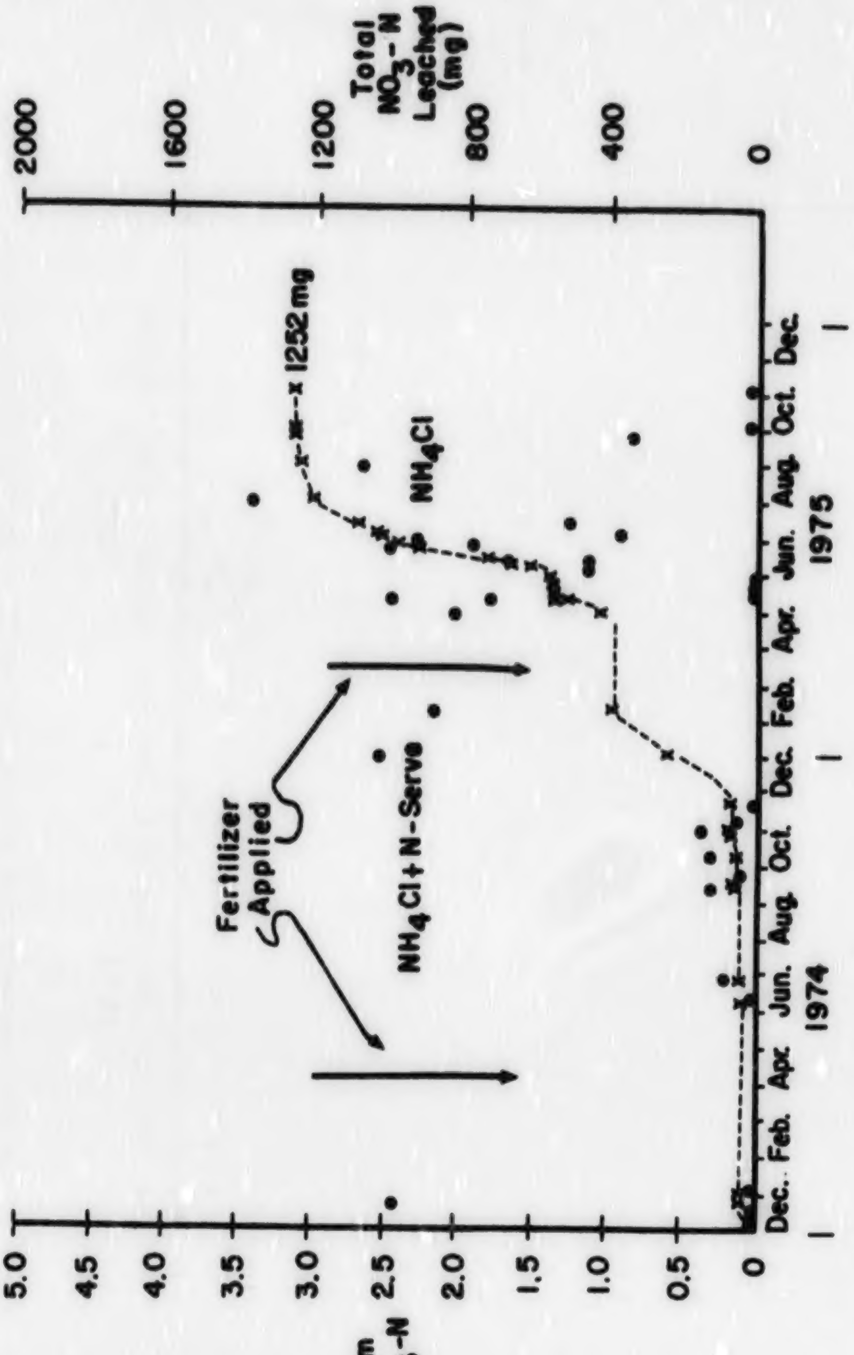

Figure 14. Concentration and cumulative NO_3-N found in drainage from Lysimeter 3 during 1974 and 1975 and fertilized with NH_4Cl treated with N-Serve and NH_4Cl.

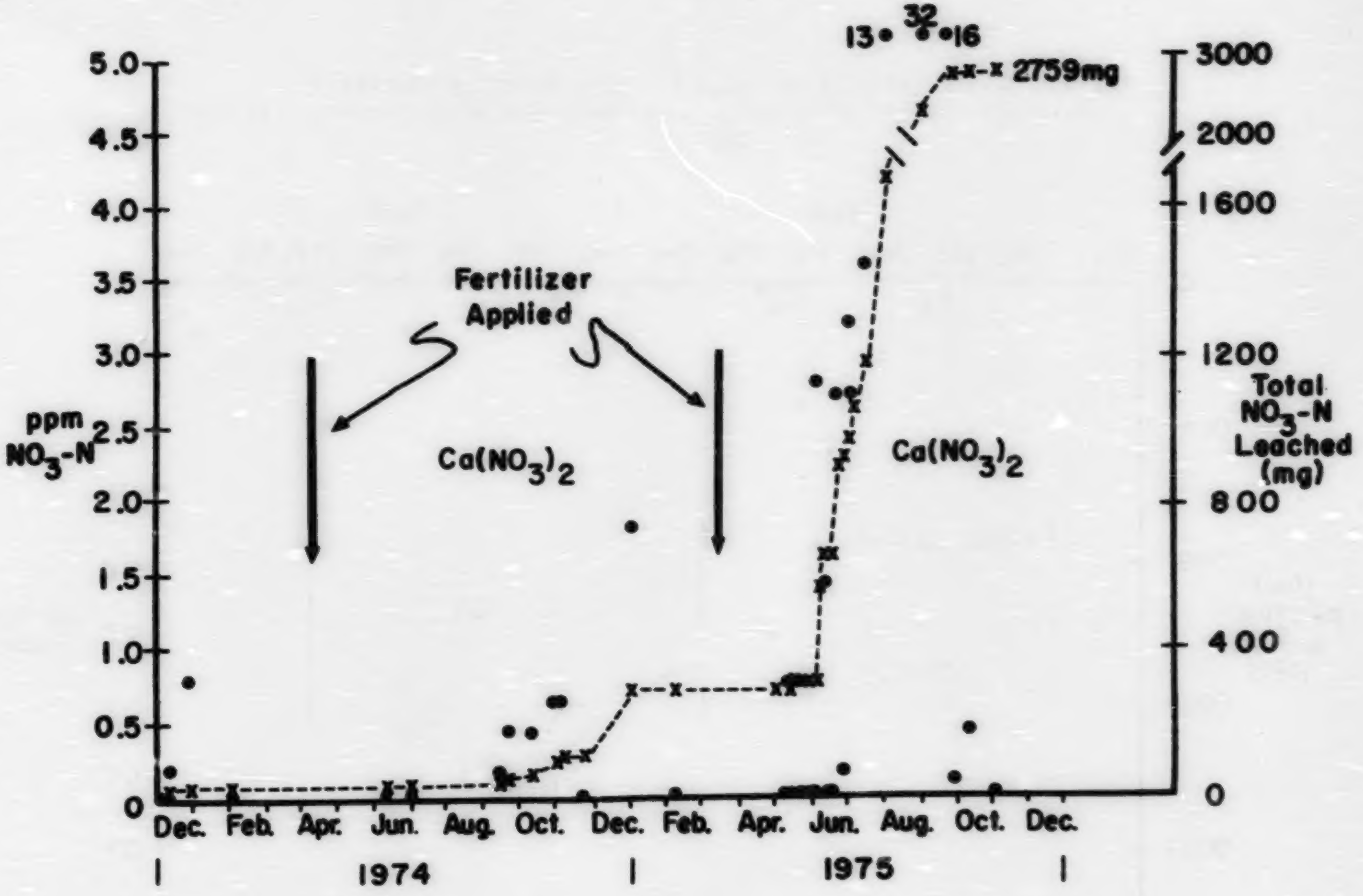

Figure 15. Concentration and cumulative NO_3-N found in drainage from Lysimeter 4 during 1974 and 1975 and fertilized with $Ca(NO_3)_2$.

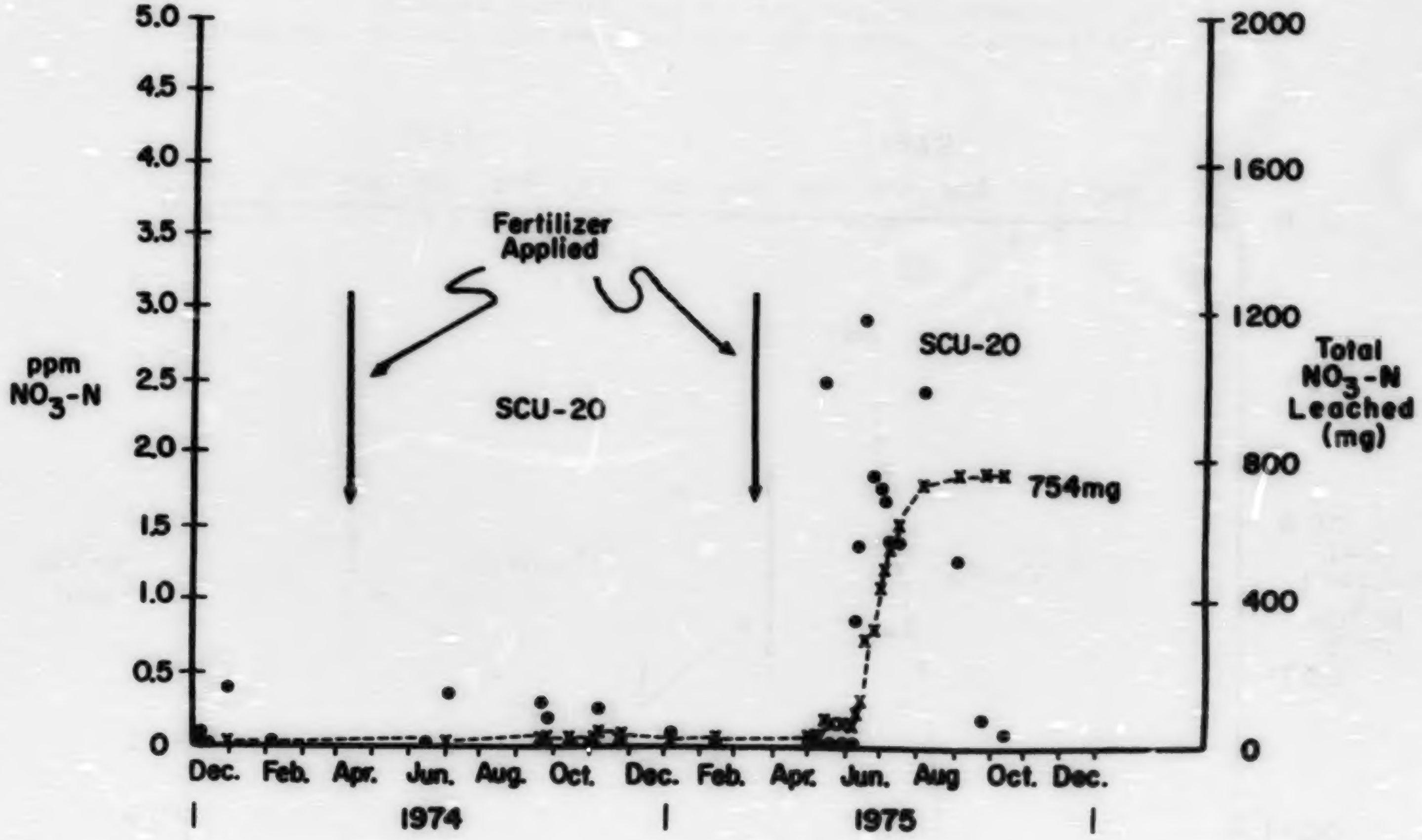

Figure 16. Concentration and cumulative NO_3-N found in drainage from Lysimeter 5 during 1974 and 1975 and fertilized with SCU-20.

occurred in December of 1973, prior to fertilization. The percent of nitrogen fertilizer lost by leaching through the lysimeters ranged from 0.04% from the SCU-20 to 0.23% from the $Ca(NO_3)_2$. The very low level of leaching in 1974 is attributed to the low amount of rainfall received after the application of fertilizer. The maximum amount of leaching effluent collected from the time of fertilization to the end of December in 1974 was only 3.6 cm from lysimeter 4. The least amount of effluent collected during this same period of time was 0.9 cm from lysimeter 5. Drainage through the five lysimeters was different due to heterogeneity in the soil profiles. Being an alluvial soil, there was considerable variability in the texture of the soil with depth. A supplemental study was undertaken to determine the variability of the soil profiles with respect to moisture retention, bulk density, and texture. The results of this investigation are given in the Appendix.

Leaching was insignificant during the first part of 1975 due to below normal rainfall. However, heavy rains in May and June caused increased water movement which caused the concentration of NO_3 in the effluents to increase significantly. Concentrations between 1-3 ppm were common in the effluents collected in May through August of 1975. The NH_4Cl treatments with or without N-Serve additions generally resulted in lower NO_3-N concentrations in the effluent. The $Ca(NO_3)_2$ treatment was the only fertilization practice which resulted in concentrations greater than 6 ppm occurring in the leachate. Three samples were collected from this treatment in August and September which had concentrations of 13, 32, and 16 ppm (Figure 15). The last effluent sample collected in September from lysimeter 2 and fertilized with NH_4Cl (Figure 13) had a NO_3-N concentration of 5.5 ppm which may indicate that high concentrations of nitrate were beginning to move through this lysimeter.

The total amounts of nitrogen leached during 1975 was relatively low. The greatest amount of nitrogen lost by leaching in 1975 was 2.48 gms from the $Ca(NO_3)_2$ treatment which amounts to 6.0% of the nitrogen applied in 1975. The leaching losses from the other treatments ranged from 0.78% to 2.1% of the nitrogen applied. The actual amount of NO_3-N lost from each fertilizer treatment during the two years is shown in Figures 12-16.

It is believed that some of the NO_3 leached in 1975 was from fertilizer applied in 1974. It is apparent from the data shown that leaching was occurring over six months after fertilizer was applied in 1975 and some leaching was occurring almost a year after it was applied in 1974. The 2.48 gms of nitrogen reported leached in 1975, probably was not all from the nitrogen applied in 1975. The low amount of leaching water which occurred in 1974 was probably not sufficient to move the NO_3 through the entire 120-cm profile in 1974. When the heavy leaching rains in the late spring and summer of 1975 occurred, the nitrates which remained in the lower profile from 1974 were probably leached together with some of the nitrogen applied in 1975. Nitrogen-15 was applied in 1974 and 1975 to two of the lysimeters to determine the contributions from year to year but the concentrations of NO_3 and N-15 in the effluent were too low to determine this effect.

Soil Nitrates

Soil samples were collected on October 2, 1974, May 23, 1975, and August 7, 1975, from the plots adjacent to the lysimeter. The results of these samplings are shown in Tables 53-55. Ammonium was not detected in any of the samples at any sampling time. Soil NO_3-N concentrations were extremely low in the October 1974 sampling (Table 53). Nitrate concentrations in effluents in the summer and fall of 1974 were also very low indicating that very low concentrations would be expected in the soil profiles. Since leaching of nitrates was not significant in 1974 and only about 20% of the applied N was found in the grain sorghum, and since no nitrates were found in the soil profile six months after fertilizer application, it is apparent that immobilization of much of the fertilizer N occurred in 1974.

Following the application of nitrogen in March of 1975, soil samples were taken on May 23. The concentrations of NO_3-N in the soil profiles were rather high, except for lysimeter 3 which was fertilized with NH_4Cl. The concentrations between 90-105-cm were considerably lower, indicating that movement of NO_3 had not reached this depth and that leaching effluents should not contain much NO_3. The effluents collected from the lysimeters after the application of fertilizer were on May 3. Figures 12-16 indicated that the effluent concentrations the first of May were indeed low.

Figure 14 and Table 54 indicate that some of the N applied as NH_4Cl had leached from lysimeter 3 as NO_3 by the later part of May. The concentration of NO_3 in the effluents in May was relatively high with values between 1.8 and 2.5 ppm. The soil samples from the plot treated with NH_4Cl and being adjacent to lysimeter 3 indicated that very little nitrate remained in the soil above 105-cm on May 23. The high nitrate concentrations found in the other profiles on May 23 (Table 55) indicate that leaching of these nitrates could be significant if sufficent rainfall occurred to cause drainage before plant uptake or immobilization removed the NO_3 from the soil solution. Heavy rains did indeed occur in June, July, and August. Figures 12-16 indicate the extent of leaching which did occur during this period.

Soil samples taken following the heavy rains (Table 55) indicate that most of the NO_3 had been leached lower in the soil and a considerable amount leached from the soil. However, much of the decline in soil NO_3 concentration can be attributed to plant uptake.

TABLE 53. CONCENTRATION OF NO_3-N IN SOIL OF LYSIMETERS ON OCTOBER 2, 1974

	Lysimeter				
Depth (cm)	1	2	3	4	5
	ppm				
0 - 8	0.1	0.2	0.4	0.2	0.2
8 - 15	1.0	0.1	0.3	0.2	0.3
15 - 22	0.3	0.1	0.3	0.2	0.2
22 - 30	0.3	0.1	0.2	0.2	0.1
30 - 45	0.1	0.1	0.2	0.2	0.1
45 - 60	---	0.1	0.2	0.2	0.2
60 - 75	0.1	0.2	0.2	0.3	0.3
75 - 90	0.1	0.1	0.2	0.2	0.2
90 -105	0.1	0.2	0.2	0.1	---

Each value is an average of two samples

TABLE 54. CONCENTRATION OF NO_3-N IN SOIL OF LYSIMETERS ON MAY 23, 1975

	Lysimeter				
Depth (cm)	1	2	3	4	5
	ppm				
0 - 8	---	1.5	0.5	0.6	2.7
8 - 15	---	3.6	1.6	11.6	2.6
15 - 22	0.9	11.5	0.9	30.9	4.6
22 - 30	0.6	37.1	0.6	18.6	10.1
30 - 45	0.6	26.9	0.8	36.3	24.6
45 - 60	5.8	36.8	2.6	25.2	11.1
60 - 75	19.1	26.6	3.1	10.5	8.3
75 - 90	18.3	18.2	2.3	3.9	5.4
90 -105	2.5	9.6	2.2	4.8	2.0

Each value is an average of two samples

TABLE 55. CONCENTRATION OF NO_3-N IN SOIL PROFILE OF LYSIMETERS ON AUGUST 7, 1975

	Lysimeter				
Depth (cm)	1	2	3	4	5
	ppm NO3-N				
0 - 8	0.9	3.1	0.6	1.5	2.1
8 - 15	0.8	5.5	0.8	1.6	2.1
15 - 22	0.9	7.2	0.9	1.3	2.1
22 - 30	1.2	10.4	0.6	1.9	2.5
30 - 45	1.2	8.1	0.8	4.7	1.6
45 - 60	1.0	5.0	0.8	10.5	0.9
60 - 75	1.9	2.3	0.9	16.7	1.0
75 - 90	2.8	12.1	0.8	26.9	---
90 -105	---	---	---	---	---

Each value is an average of two samples

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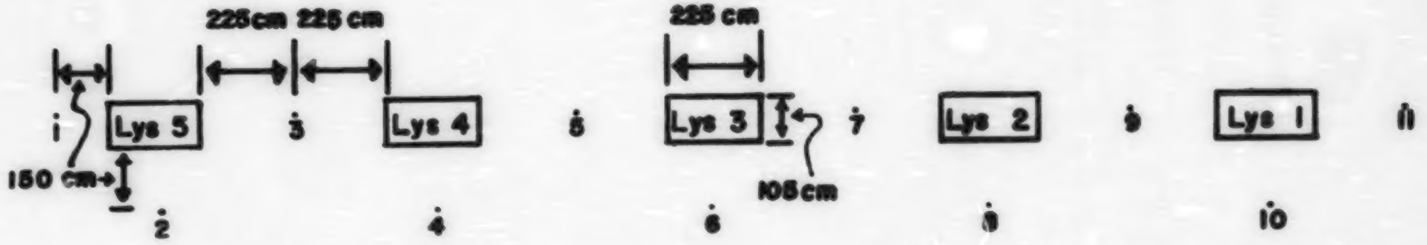
APPENDIX

Undisturbed soil samples were taken around the 5 lysimeters described in Section VIII to determine the particle size distributon, bulk densities and moisture retention characteristics of the soil profiles. Eleven profiles were sampled to depths of 141-154 cm. Undisturbed cores were taken approximately every 3-10 cm with a core sampler fitted with a brass cylinder sleeve 5 cm in diameter and 3.75 cm in length.

Moisture retention characteristics were determined on each sample by the method described by Klute (Klute, 1965). Basically, the method consists of placing the undisturbed cores on a porous plate in a specially designed pressure cell. The cores are saturated with water by wetting from the bottom. The samples are allowed to drain by applying desired air pressure to the top of the soil core. After drainage ceases the cell and soil core are weighed and a slightly higher air pressure applied until drainage again ceases. The cell is weighed to determine moisture loss caused by the added air pressure. This process is repeated until a pressure of 1 bar is reached. Pressure increments of 0.1 bar were used in this study.

Bulk density of the soils were determined by drying the undisturbed soil cores used in the moisture retention study at a temperature of 110° C. Using the weight of soil contained in the known volume of the cylinder sleeves the bulk density was determined.

Particle size distribution was determined on the undisturbed soil cores by the Hydrometer Method as described by Day (Day, 1965). The same soil samples which were used for the water retention and bulk density determinations were used for this determination.



APPENDIX A

Location of profiles with respect to lysimeters which were sampled for texture, bulk density, and moisture retention.

APPENDIX B

TABLE B-1. PARTICLE SIZE ANALYSIS AND BULK DENSITIES OF SOIL SAMPLES FROM PROFILES IN LYSIMETER PLOTS

Profile Location	Sample No.	Depth (cm)	% Sand	% Silt	% Clay	Bulk Density
1	1	6 - 9	35	55	10	1.42
	2	13 - 16	27	60	13	1.57
	3	21 - 24	29	58	13	1.63
	4	30 - 33	15	69	16	1.48
	5	42 - 45	------------lost------------------			
	6	49 - 52	69	28	3	1.32
	7	61 - 64	60	35	5	1.41
	8	74 - 77	64	25	11	1.42
	9	92 - 95	27	60	13	1.66
	10	104-107	61	28	11	1.40
	11	112-115	25	55	20	1.52
	12	120-123	16	66	18	1.50
	13	126-129	50	35	15	1.51
	14	142-145	60	30	10	
	15	150-153	32	34	34	1.53
2	1	(-1)- 2	49	30	21	1.10
	2	7 - 10	29	47	24	1.56
	3	17 - 20	23	54	23	1.59
	4	28 - 31	38	38	24	1.48
	5	39 - 42	34	59	7	1.46
	6	48 - 51	38	33	29	1.45
	7	61 - 64	65	27	8	1.43
	8	81 - 84	64	26	10	1.44
	9	94 - 97	62	27	11	1.45
	10	102-105	14	51	35	1.51
	11	121-124	46	41	13	1.51
	12	137-140	34	36	30	1.49
	13	149-152	65	25	10	1.44
3	1	4 - 7	------------lost------------------			
	2	12 - 15	39	48	13	1.45
	3	19 - 21	35	41	24	1.45
	4	25 - 28	22	65	13	1.67
	5	34 - 37	14	54	32	1.55
	6	38 - 41	29	66	5	1.54
	7	51 - 54	65	21	14	1.51

Table B-1. (Continued)

Profile Location	Sample No.	Depth (cm)	% Sand	% Silt	% Clay	Bulk Density
3	8	59 - 62	57	35	8	1.36
	9	72 - 75	54	43	3	1.32
	10	87 - 90	64	25	11	1.46
	11	99 -102	16	59	25	1.48
	12	110-113	33	52	15	1.66
	13	120-123	73	19	8	1.45
	14	132-135	50	40	10	1.48
	15	143-146	50	45	5	1.45
4	1	(-2)- 1	49	36	15	1.43
	2	8 - 11	49	33	18	1.59
	3	22 - 25	------------lost-------------------			
	4	32 - 35	15	50	35	1.43
	5	43 - 46	51	34.2	15	1.47
	6	56 - 59	48	31.3	21	1.43
	7	74 - 77	33	40	27	1.45
	8	84 - 87	55	37	8	1.37
	9	99 -102	28	54	18	1.69
	10	116-119	27	49.3	23	1.48
	11	128-131	35	52	13	1.52
	12	138-141	67	25.5	8	1.49
	13	151-154	19	63	18	1.53
5	1	4 - 7	38	38	24	1.44
	2	15 - 18	35	41	24	1.54
	3	30 - 33	72	19	9	1.48
	4	48 - 51	16	59	25	1.48
	5	60 - 63	71	18	11	1.42
	6	71 - 74	77	17	6	1.47
	7	81 - 84	50	31	19	1.49
	8	96 - 99	40	52	8	1.35
	9	110-113	40	40	20	1.42
	10	120-123	44	33	23	1.49
	11	128-131	38	52	10	1.52
	12	141-144	35	34	31	1.41
6	1	(-5)-(-2)	52	33	15	1.32
	2	6 - 9	24	46	30	1.67
	3	20 - 23	40	47	13	1.50
	4	28 - 31	23	49	28	1.44
	5	40 - 43	14	62	24	1.43
	6	56 - 59	52	34	14	1.43
	7	69 - 72	76	21	3	1.48
	8	82 - 85	52	35	13	1.53
	9	100-103	28	52	20	1.47
	10	110-113	42	38	20	1.45
	11	120-123	22	48	30	1.57

Table B-1. (Continued)

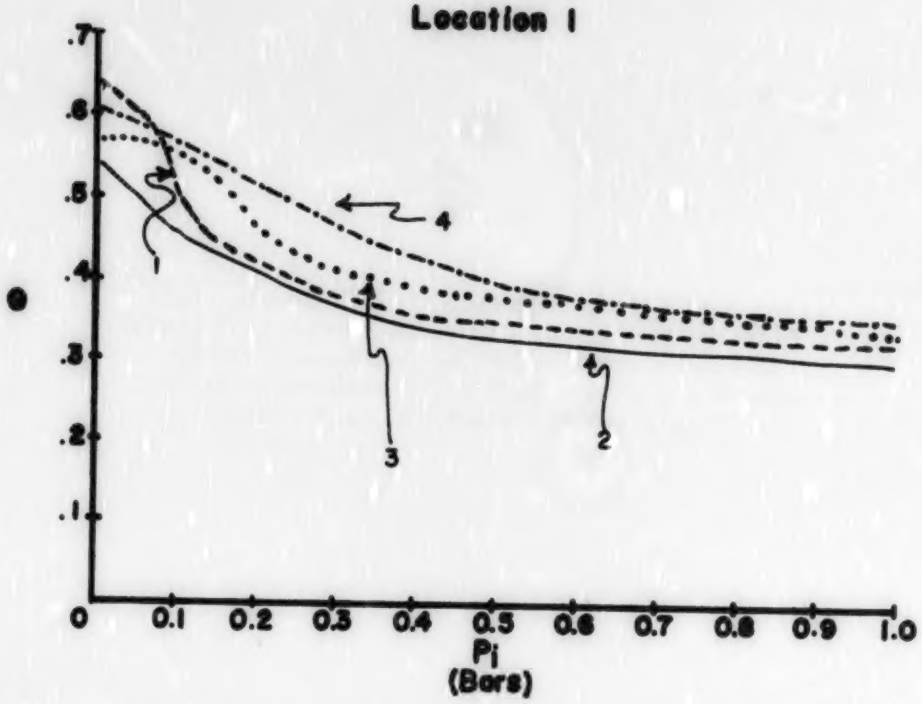
Profile Location	Sample No.	Depth (cm)	% Sand	% Silt	% Clay	Bulk Density
6	12	129-132	34	50	16	1.43
	13	145-148	46	48	6	1.53
7	1	6 - 9	44	49	12	1.49
	2	18 - 21	48	35	17	1.51
	3	36 - 39	46	33	21	1.49
	4	45 - 48	26	51	23	1.43
	5	59 - 61	24	60	16	1.34
	6	70 - 73	59	21	20	1.50
	7	84 - 87	67	20	13	1.35
	8	100-103	46	32	22	1.53
	9	104-107	42	40	18	1.34
	10	131-134	------------lost-------------------			
	11	141-144	32	44	24	1.50
8	1	(-5)-(-2)	------------lost-------------------			
	2	4 - 7	40	41	19	1.69
	3	14 - 17	40	52	8	1.58
	4	25 - 28	84	10	6	1.50
	5	43 - 46	39	53	8	1.40
	6	58 - 61	82	12	6	1.48
	7	74 - 77	64	26	10	1.51
	8	90 - 93	73	17	10	1.48
	9	100-103	60	27	13	1.46
	10	114-117	55	37	8	1.43
	11	122-125	33	40	27	1.52
	12	140-143	36	40	25	1.50
9	1	6 - 9	42	40	18	1.37
	2	14 - 21	16	56	28	1.57
	3	34 - 37	38	36	26	1.44
	4	44 - 47	29	43	28	
	5	59 - 62	31	60	9	
	6	76 - 79	30	67	30	1.48
	7	95 - 98	40	38	22	1.44
	8	107-110	28	47	25	1.62
	9	122-125	33	48	19	1.46
	10	141-144	37	46	17	1.47
10	1	(-3)- 0	40	38	22	1.52
	2	8 - 11	77	12	11	1.66
	3	24 - 27	38	41	21	1.50
	4	35 - 38	26	63	11	1.53
	5	49 - 52	56	39	5	1.37
	6	64 - 67	29	57	14	1.55
	7	81 - 84	93	0	7	1.47
	8	94 - 97	96	2	2	1.39

Table B-1. (Continued)

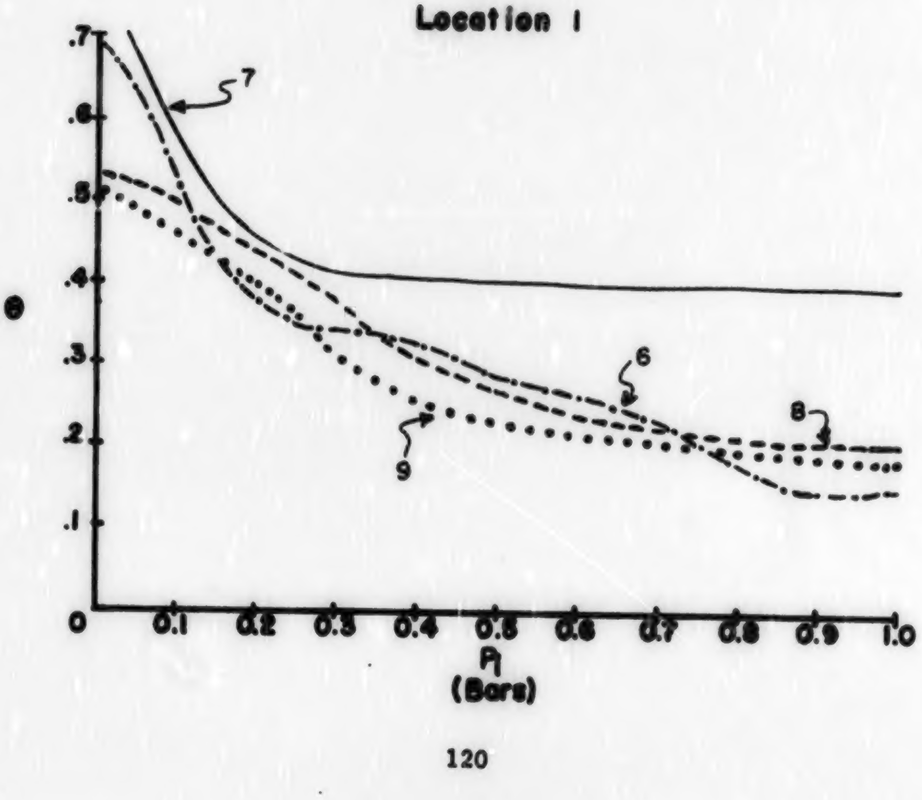
Profile Location	Sample No.	Depth (cm)	% Sand	% Silt	% Clay	Bulk Density
10	9	102-105	57	32	11	1.55
	10	116-119	52	33	15	1.49
	11	128-131	49	31	20	1.30
	12	140-143	62	24	14	1.47
11	1	(-4)-(-1)	44	46	10	1.35
	2	11 - 14	65	23	12	1.12
	3	25 - 28	67	29	4	1.40
	4	38 - 41	40	55	5	1.52
	5	60 - 63	57	30	13	1.32
	6	69 - 72	66	24	10	1.45
	7	86 - 89	46	45	9	1.48
	8	96 - 99	56	28	16	1.51
	9	109-112	52	30	18	1.48
	10	120-123	32	60	8	1.52
	11	138-141	33	57	10	1.42

APPENDIX C

Mositure Retention Curves of Soil Samples from Profiles at Various Locations Around Lysimeters. Location numbers refer to locations shown in Appendix A. Retention curve numbers refer to soil sample numbers described in Appendix B.

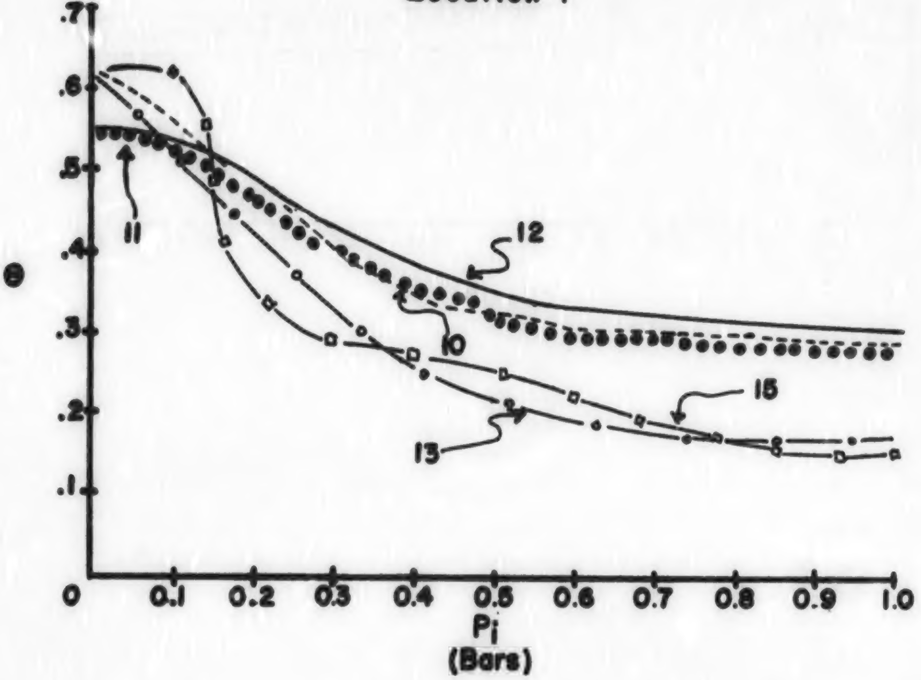


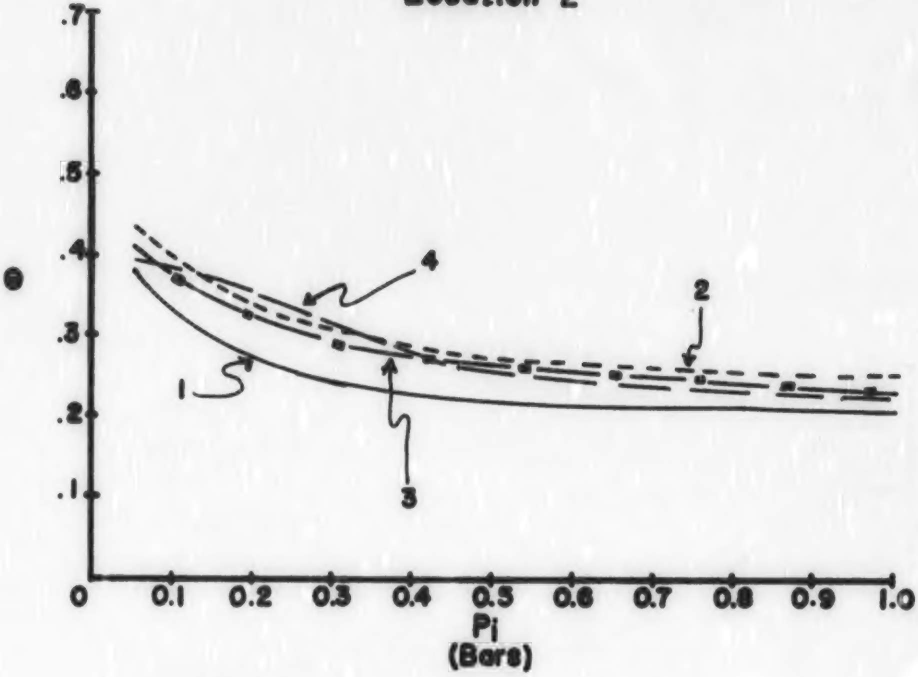
Location 1
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Pi
(Bars)
1
2
3
4



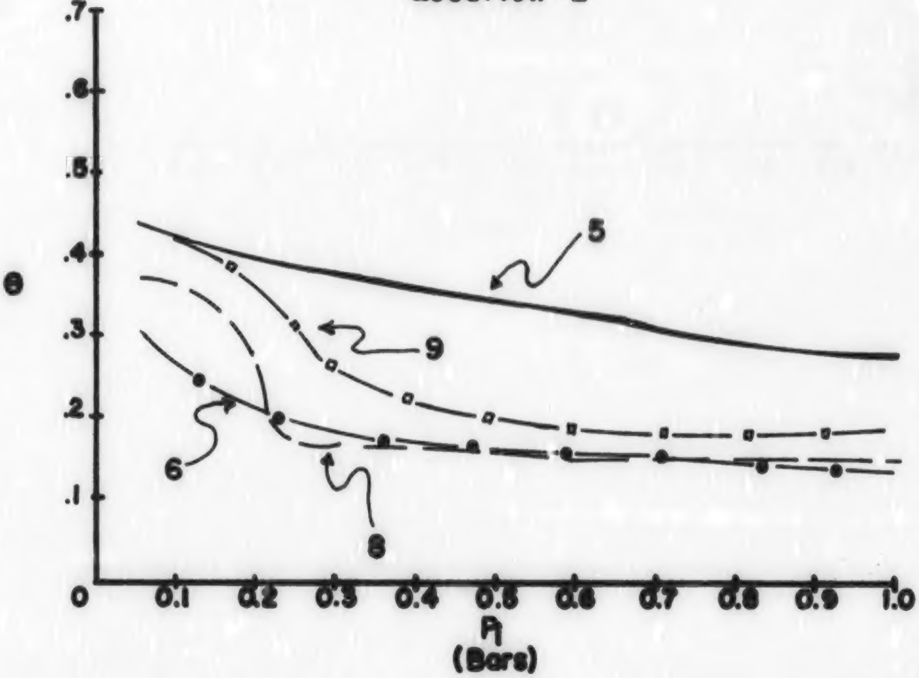
Location 1
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Pi
(Bars)
6
7
8
9

Location 1

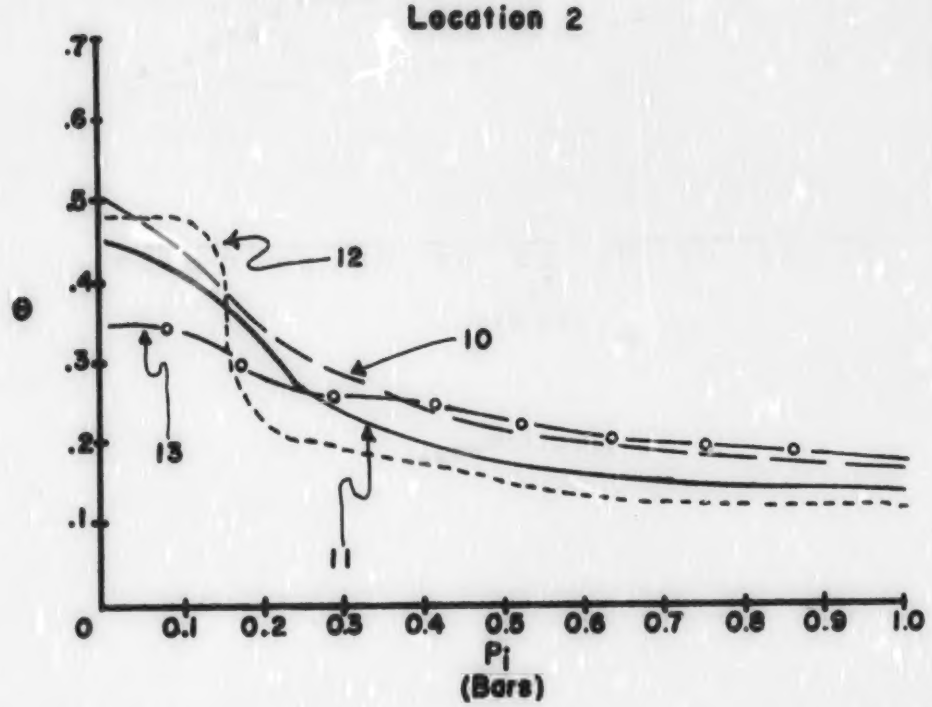




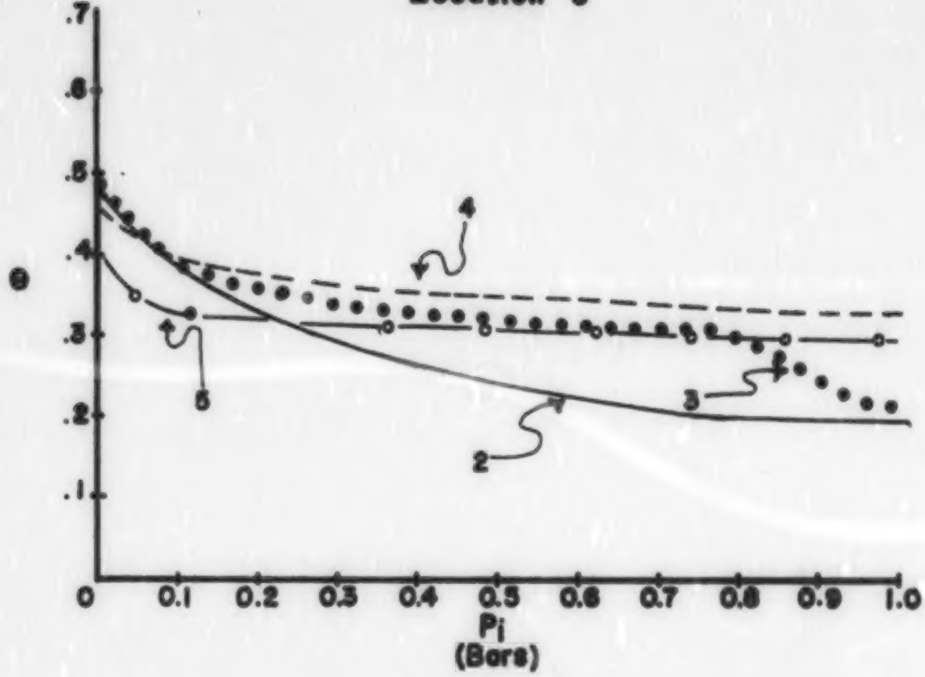
Location 2



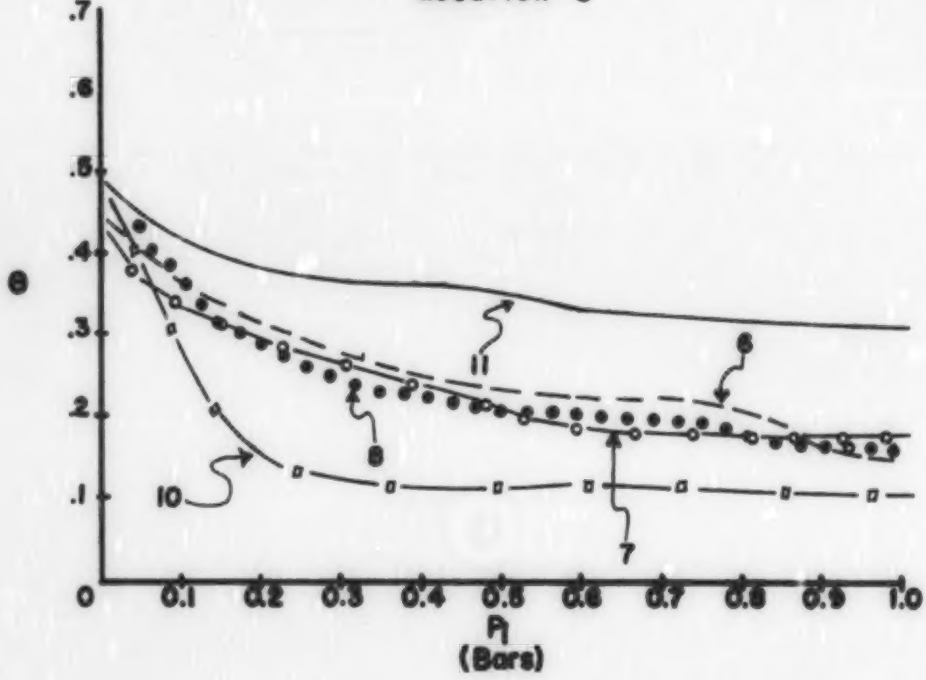
Location 2

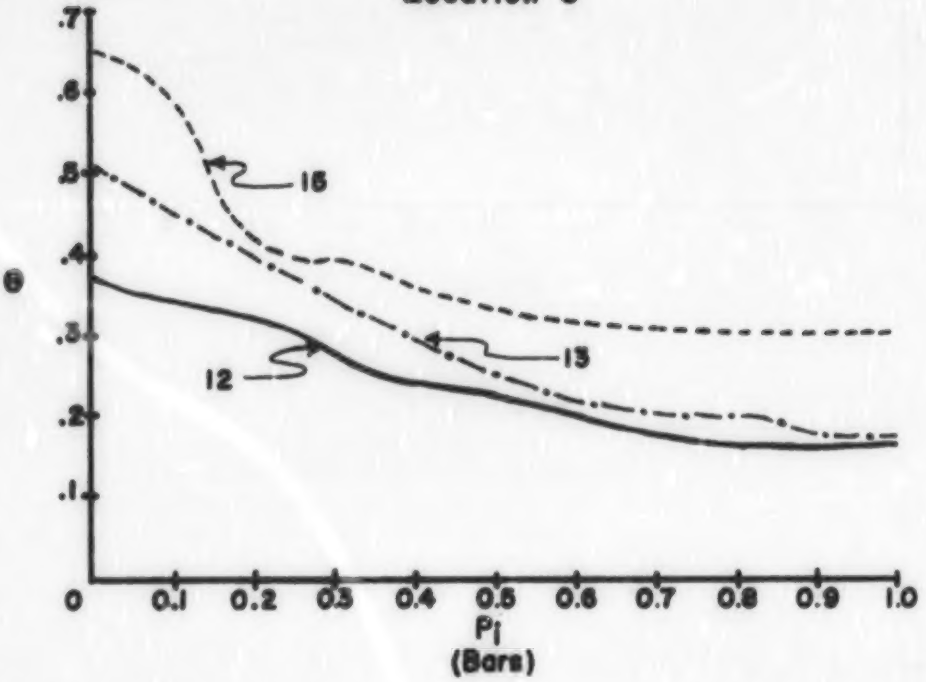

Location 2
.7
.6
.5
.4
.3
.2
.1
θ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
12
10
13
11

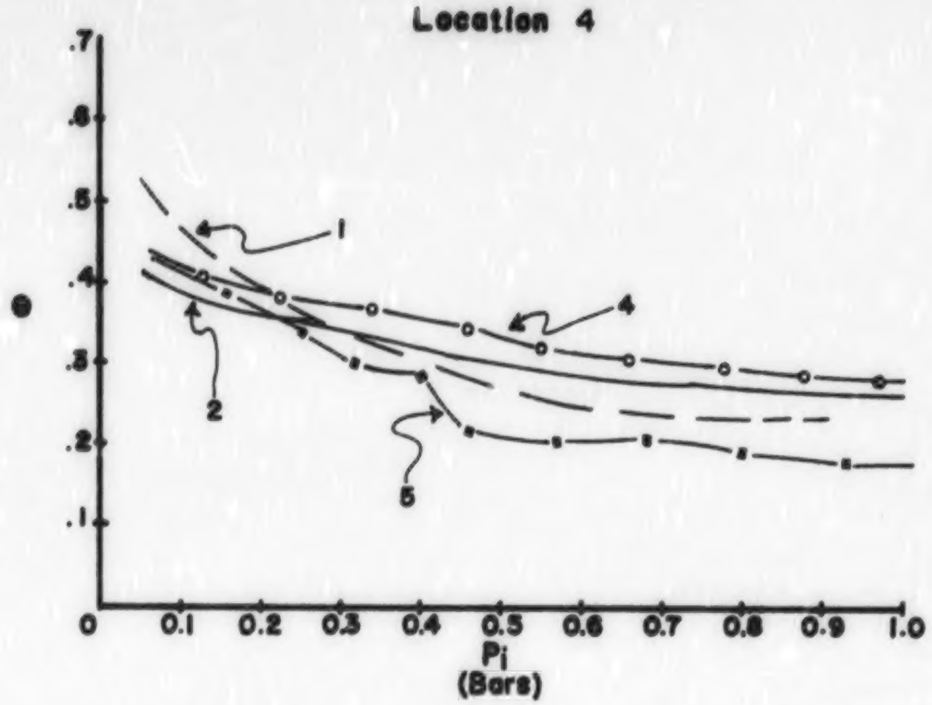
Location 3

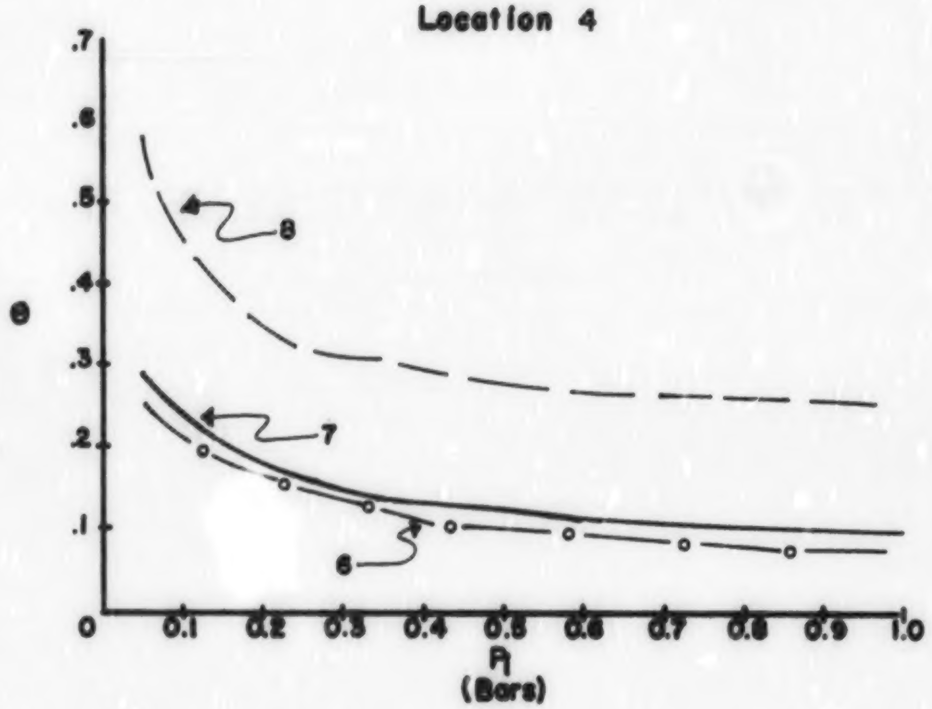


Location 3

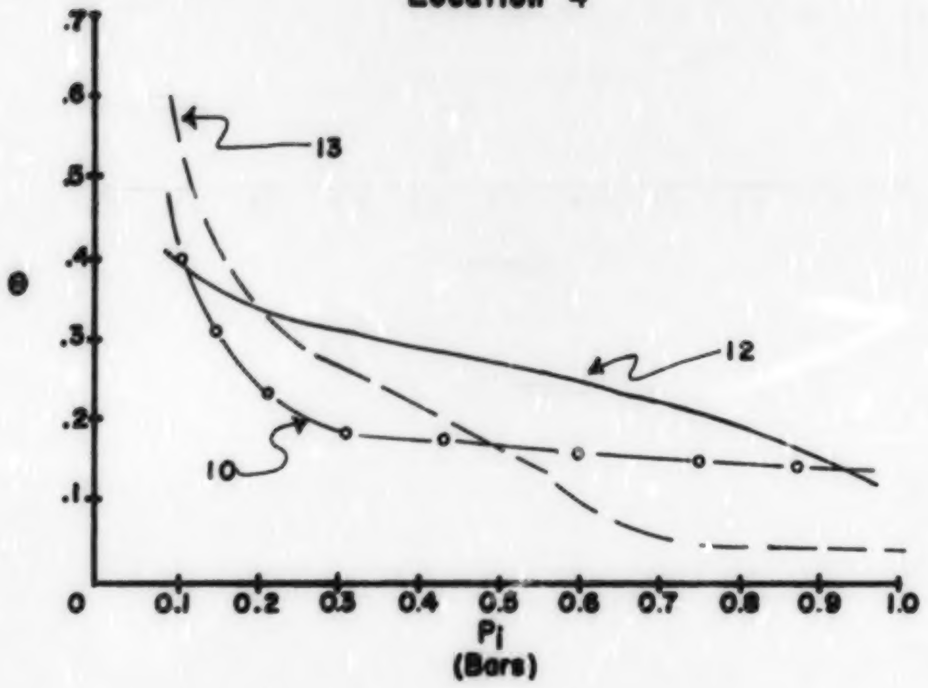


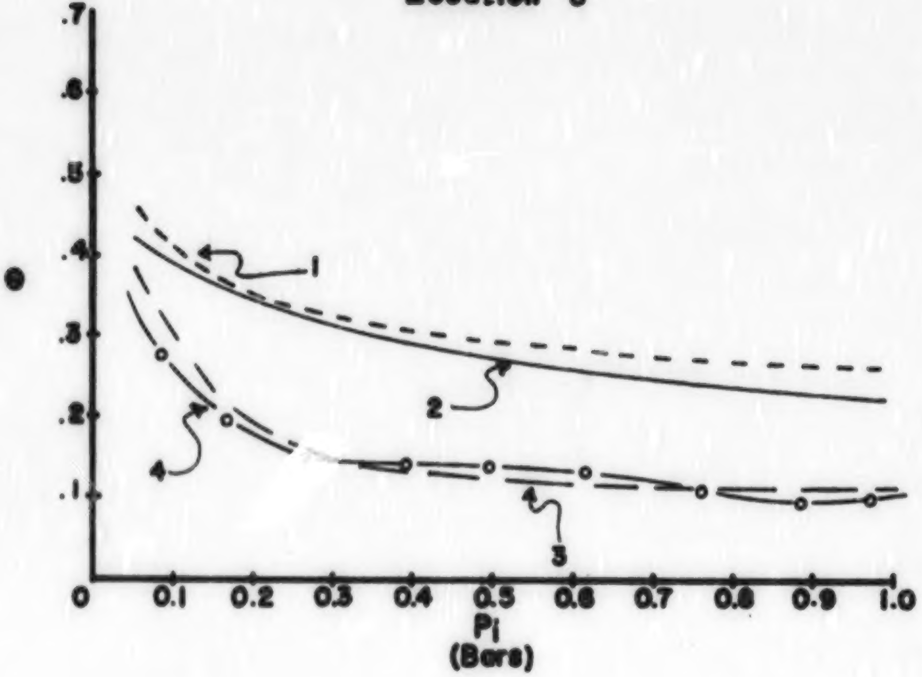

Location 3
.7
.6
.5
.4
.3
.2
.1
θ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
15
13
12

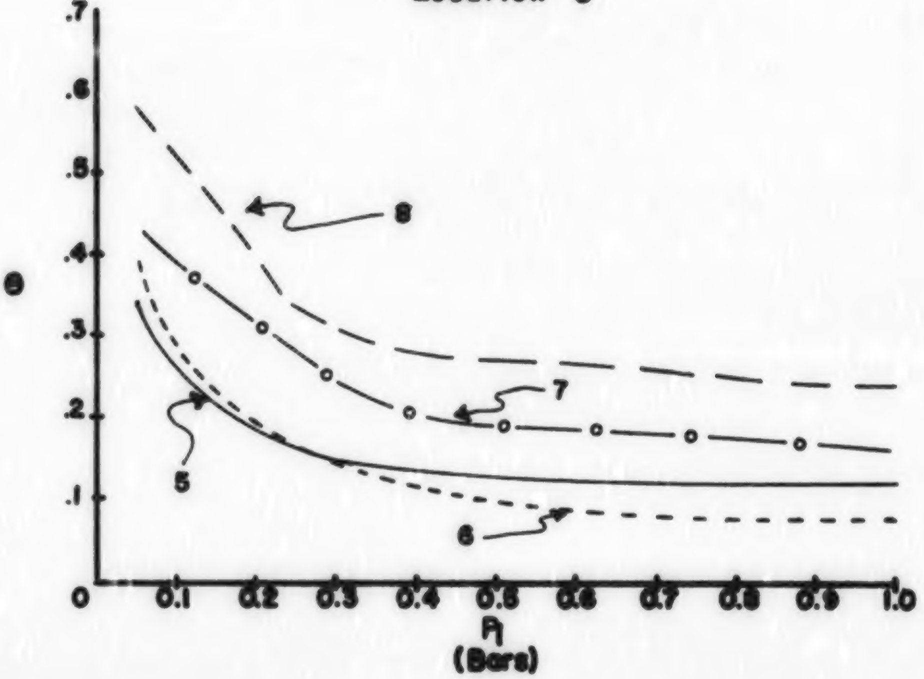

Location 4
.7
.6
.5
.4
.3
.2
.1
θ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
1
2
4
5

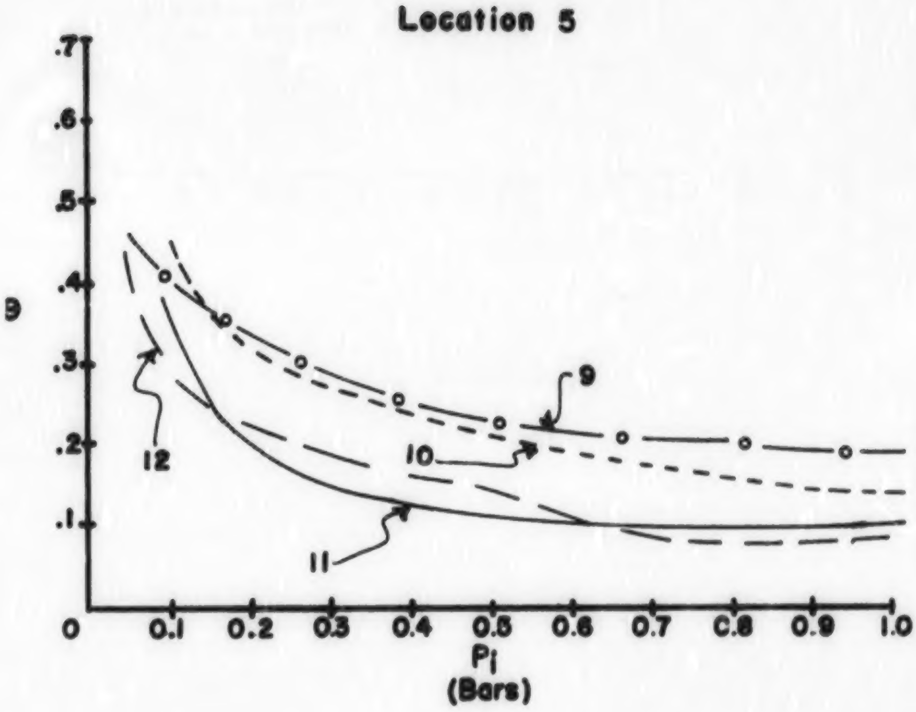

Location 4
.7
.6
.5
.4
.3
.2
.1
θ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
8
7
6

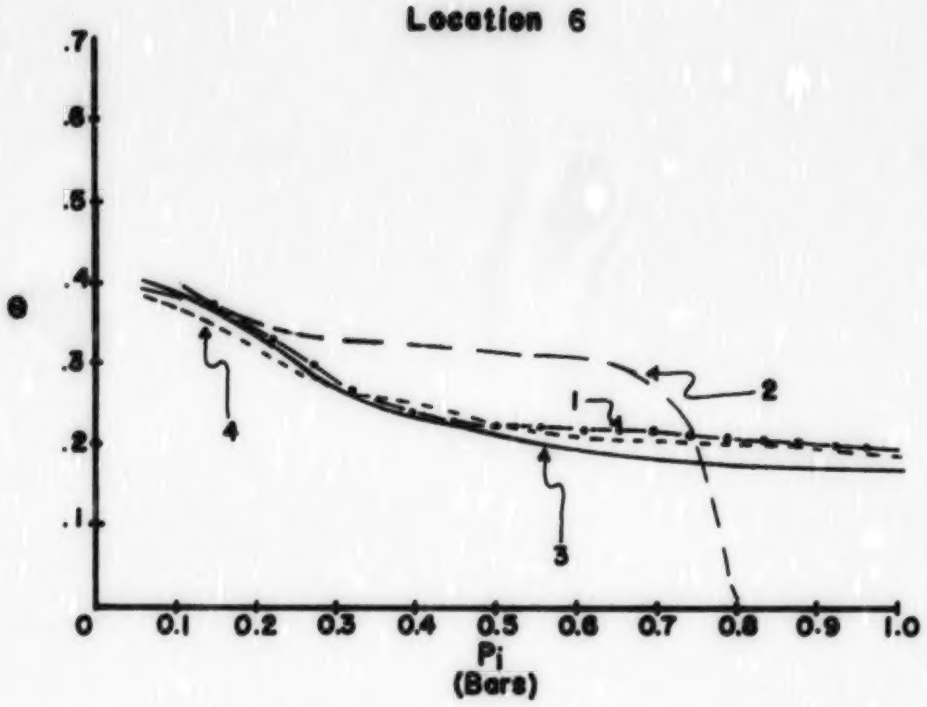
Location 4

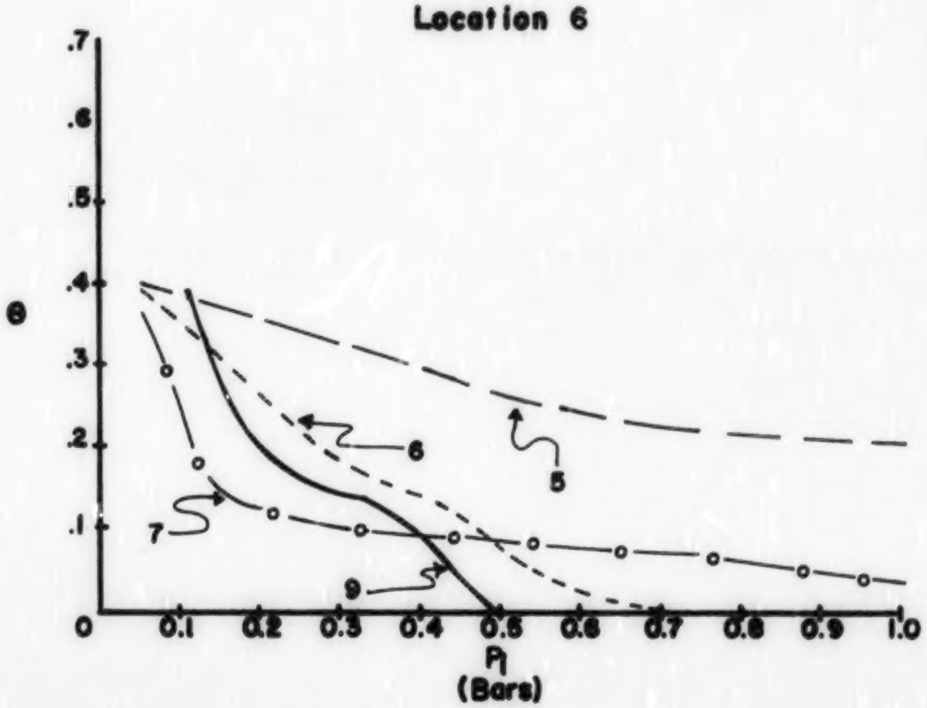


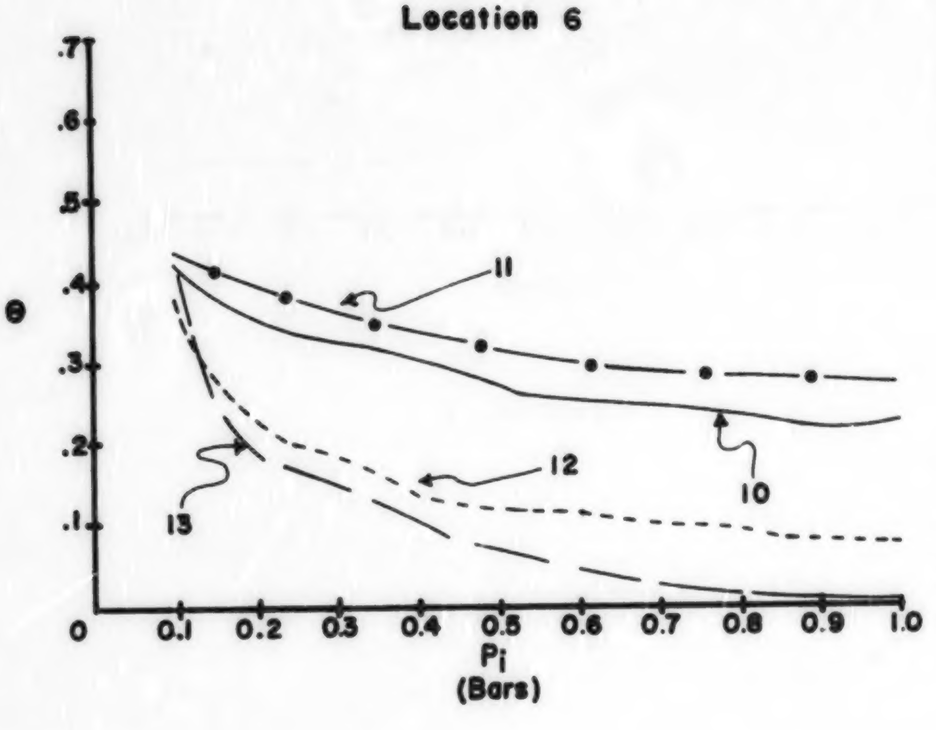

Location 5


Location 5

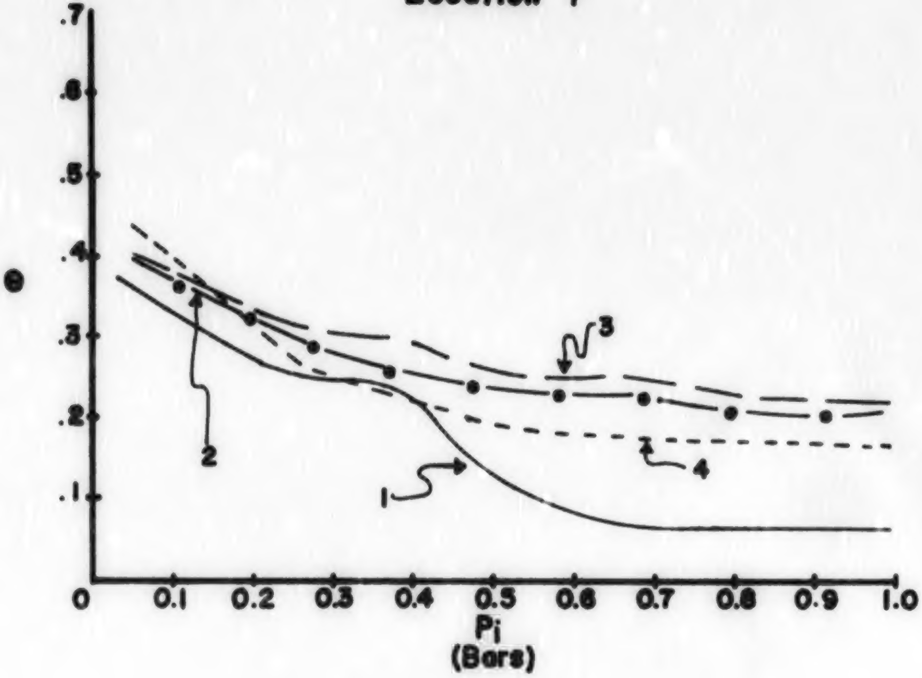

Location 5
.7
.6
.5
.4
.3
.2
.1
θ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
9
10
11
12


Location 6
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
1
2
3
4

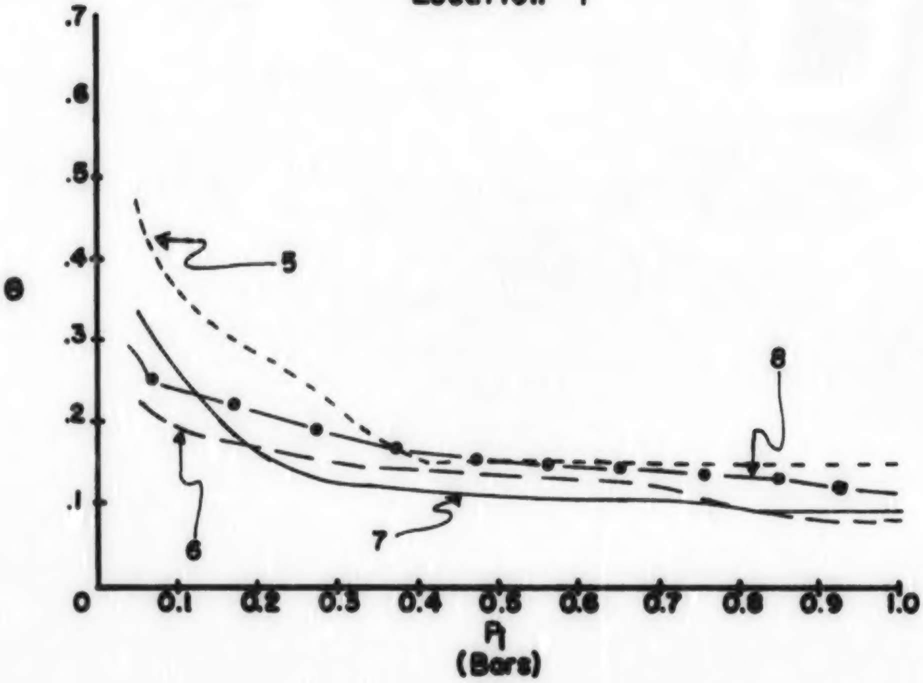

Location 6
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
5
6
7
9

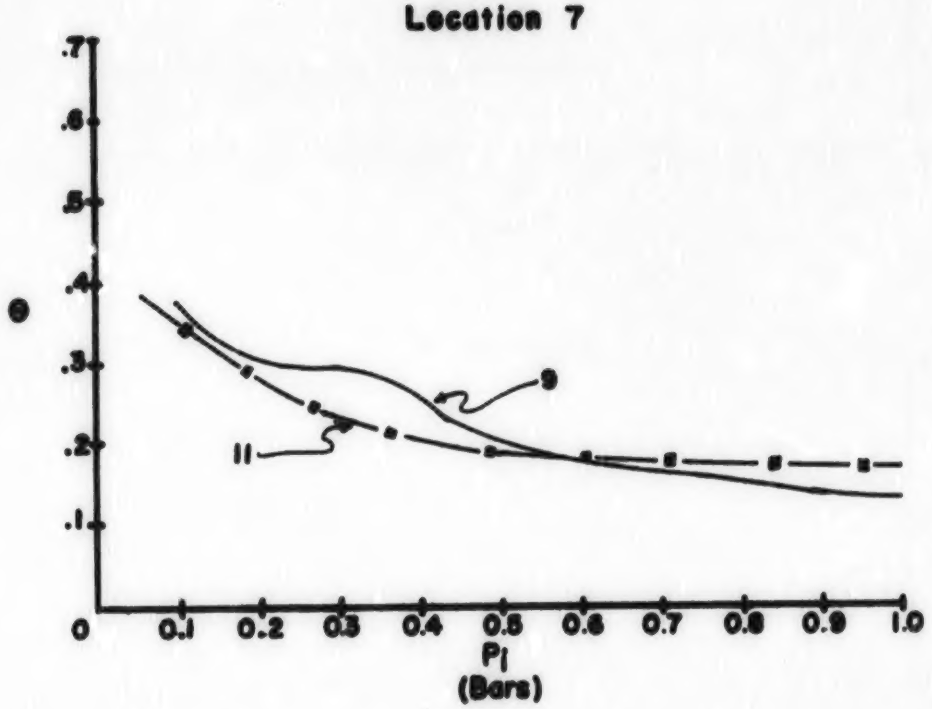

Location 6
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
11
10
12
13

Location 7

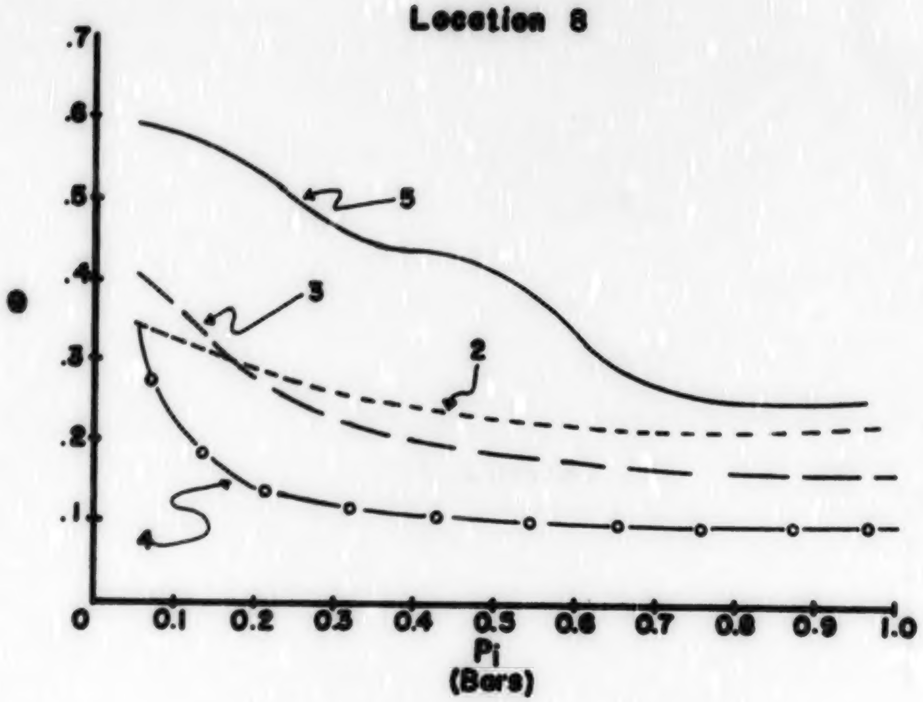


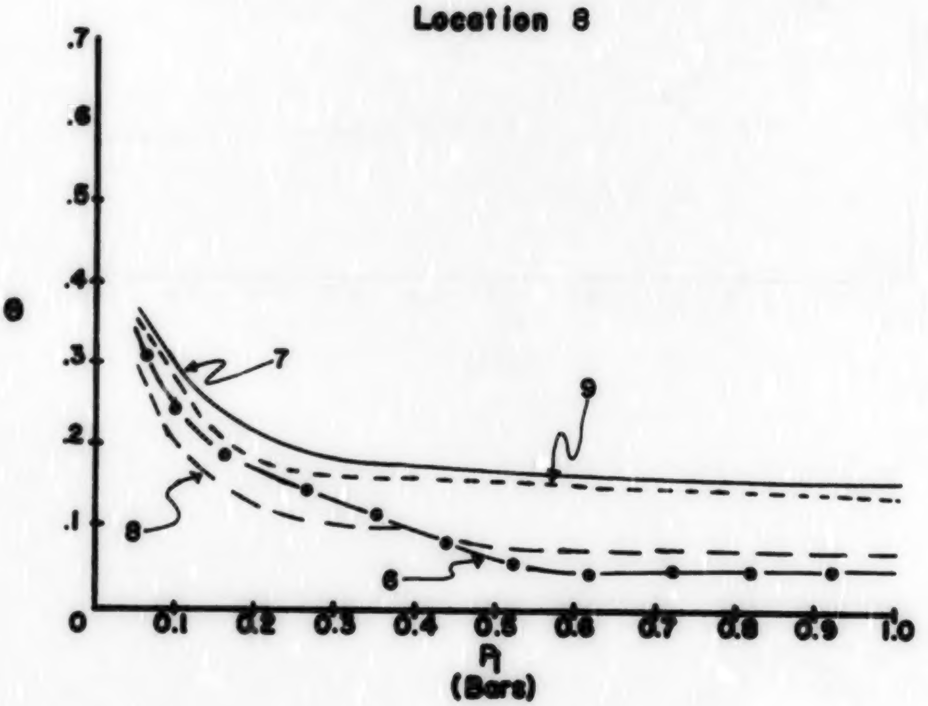
Location 7

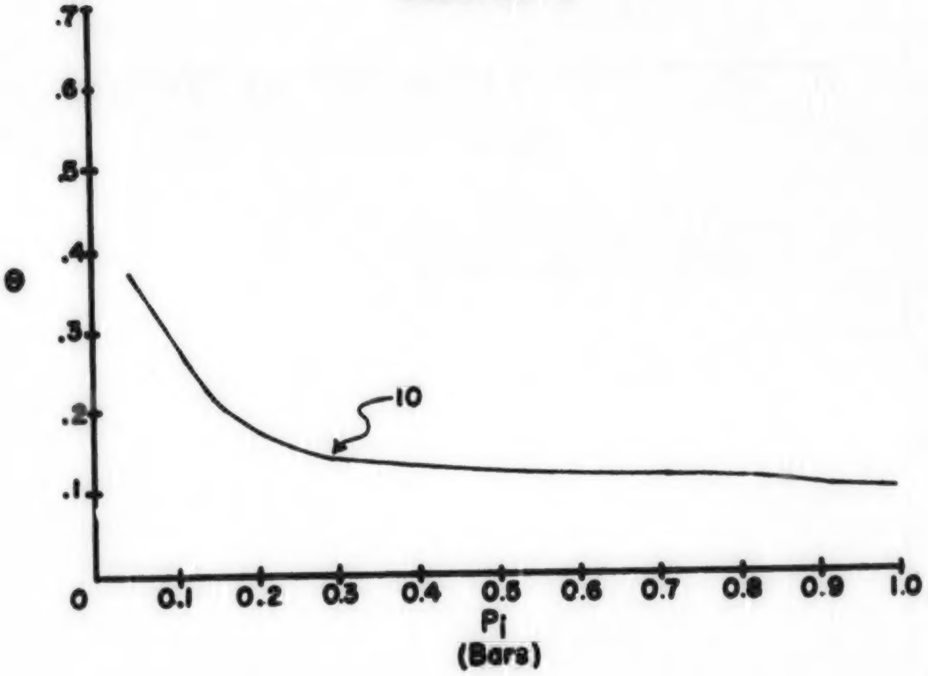




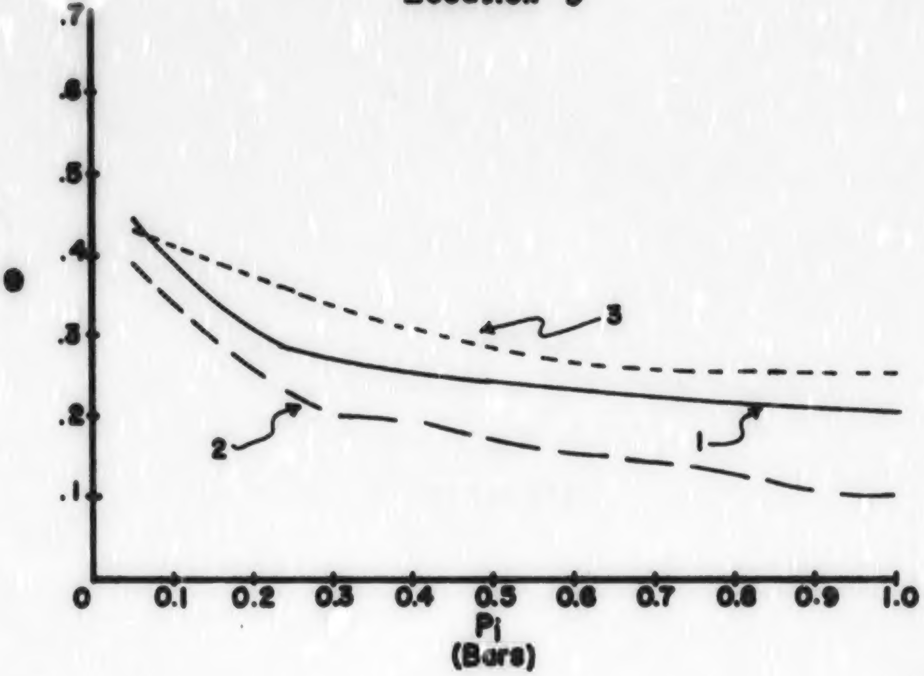
Location 7


Location 8
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Pi
(Bars)
5
3
2
4

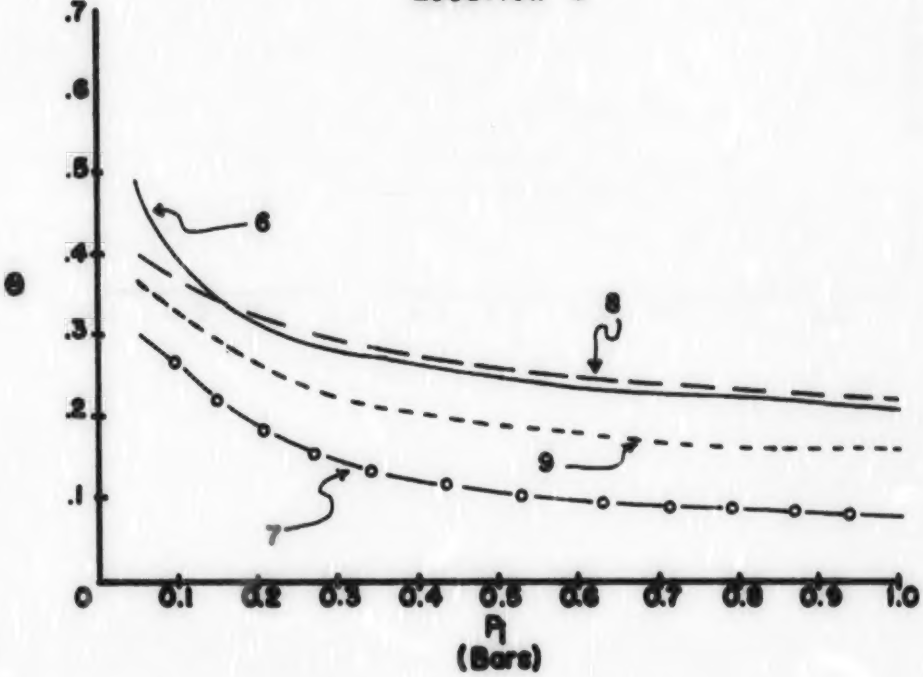

Location 8
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Pi
(Bars)
7
9
8
6



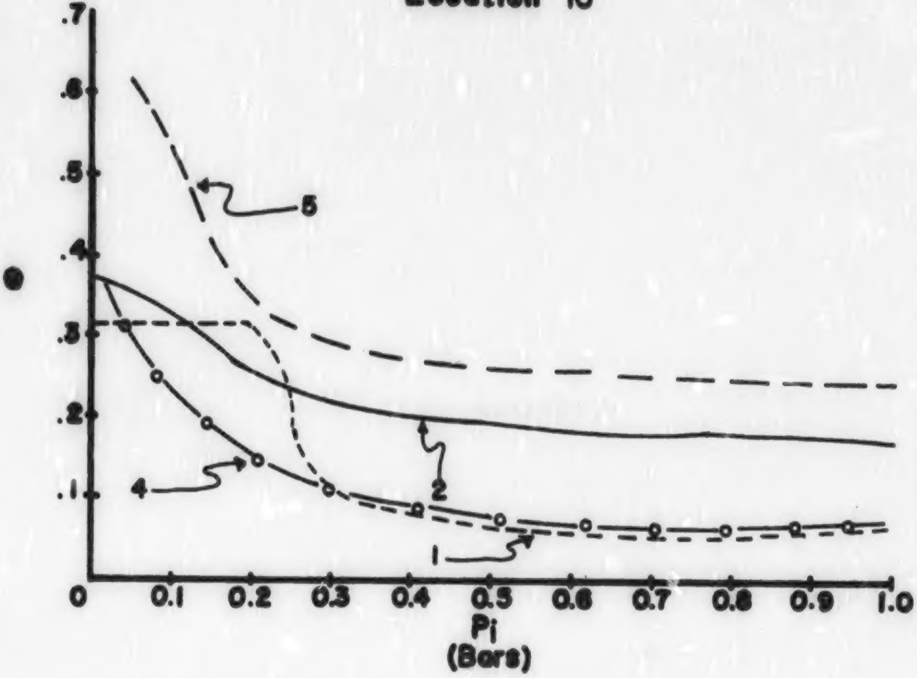
Location 8

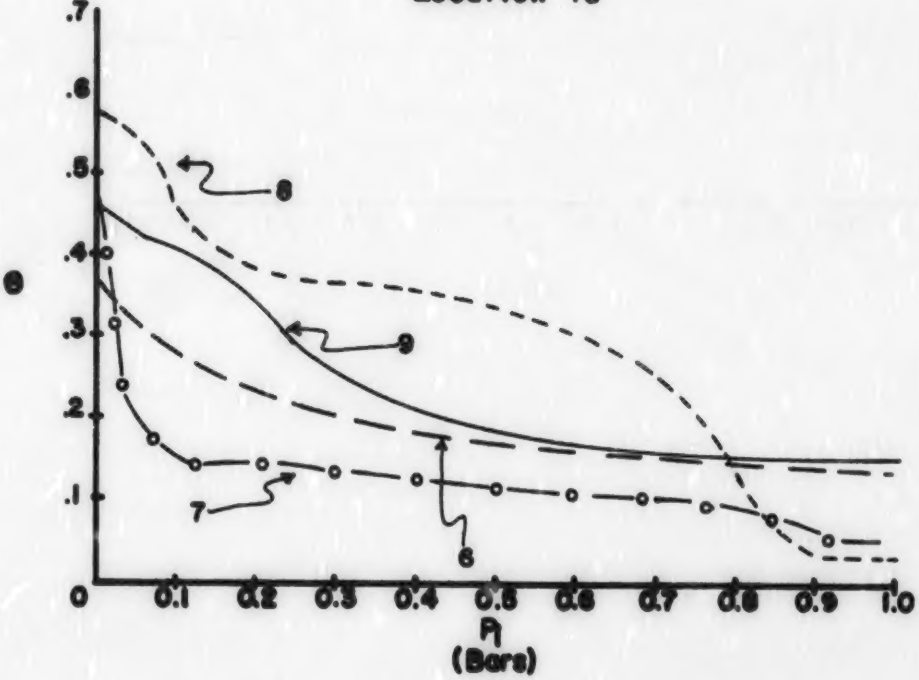


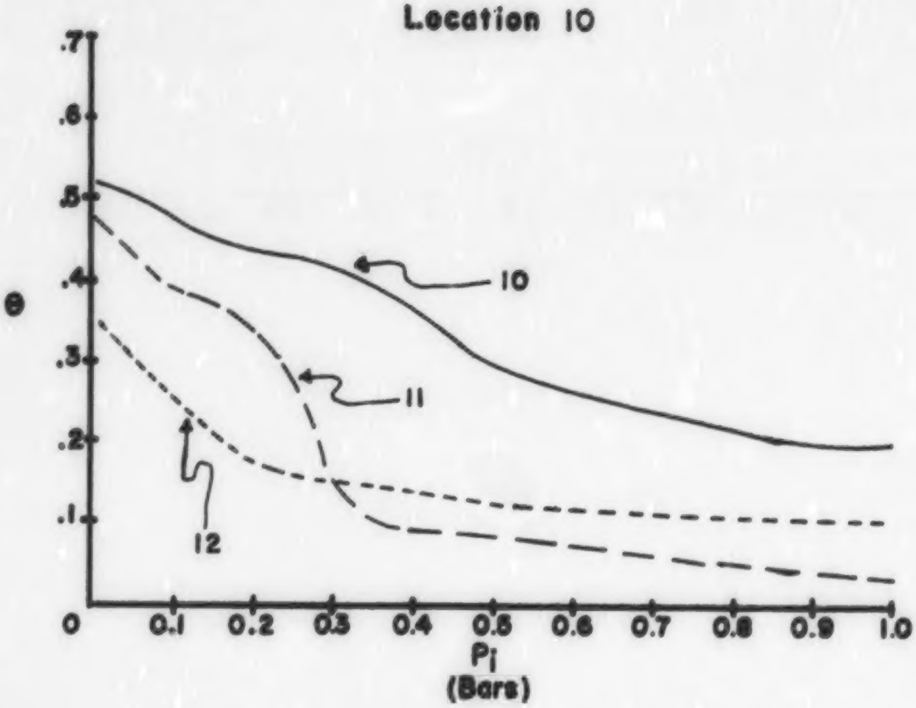
Location 9

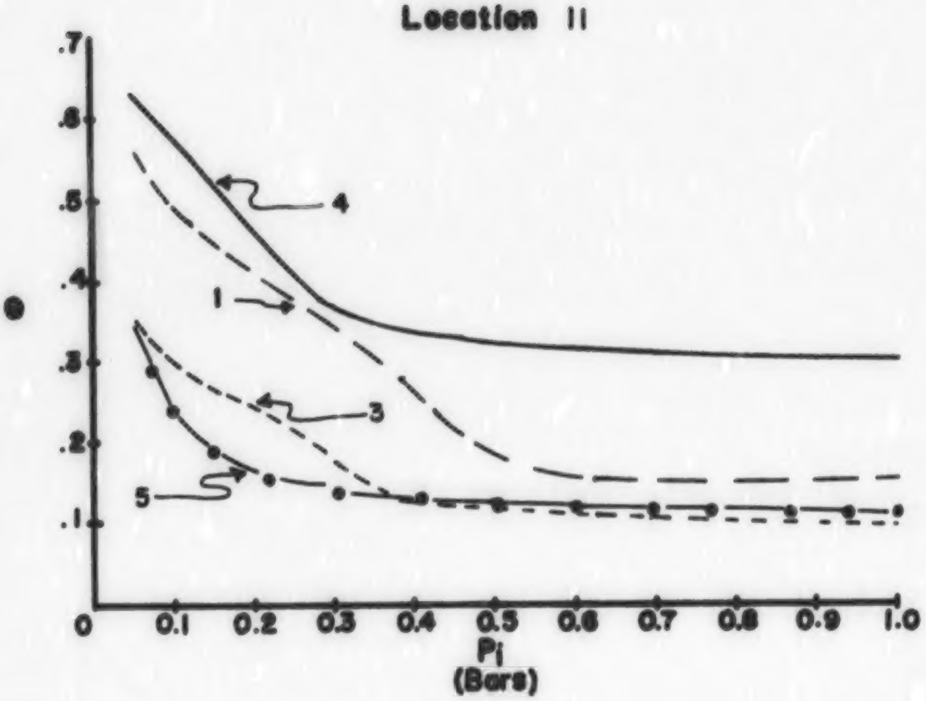


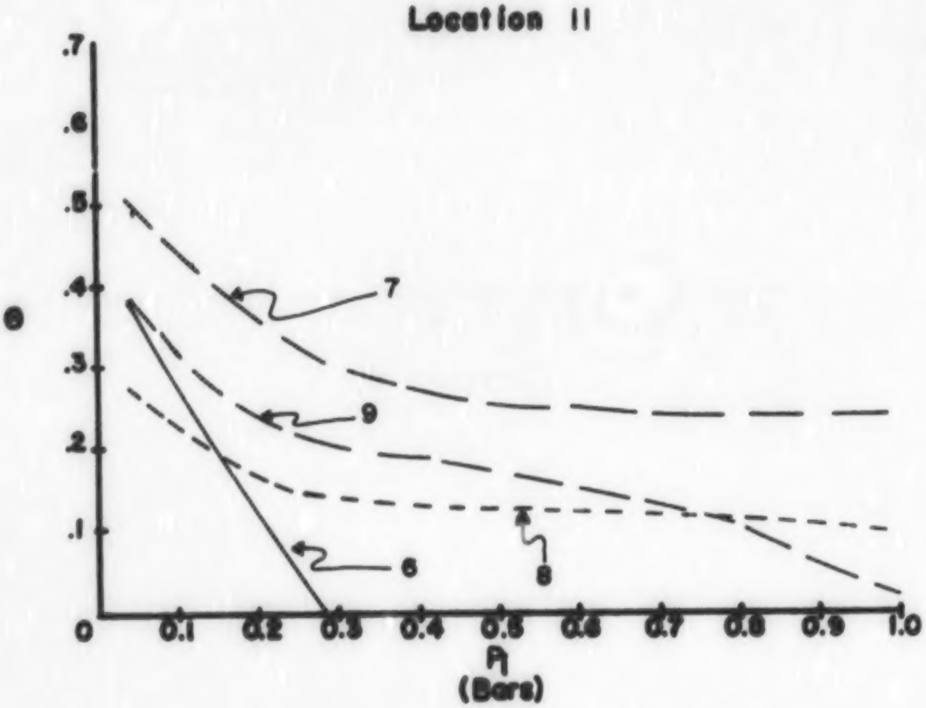
Location 9

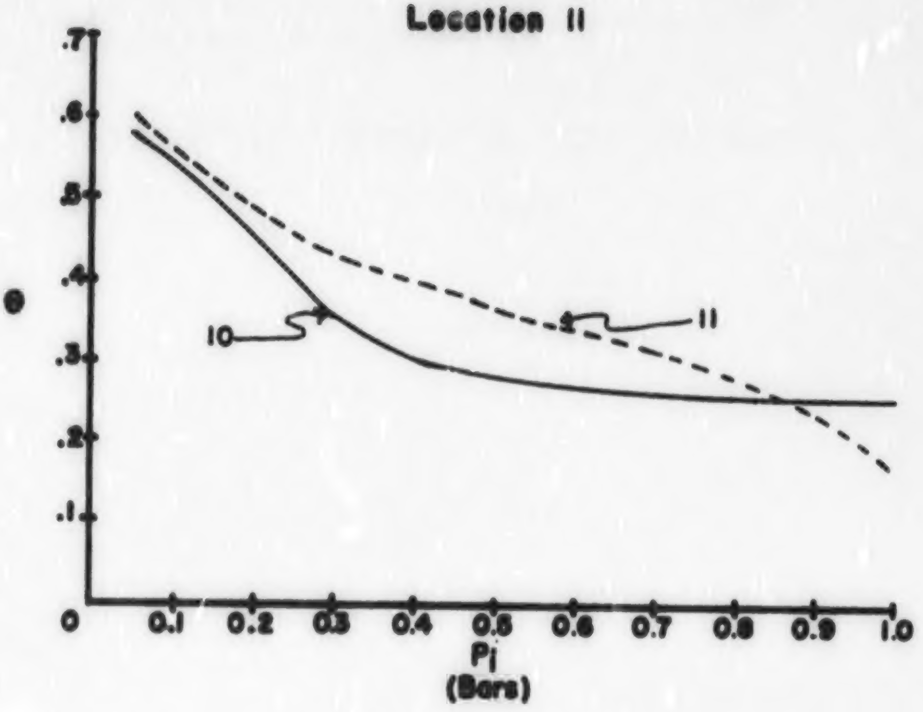

Location 10


Location 10


Location 10
.7
.6
.5
.4
.3
.2
.1
θ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
10
11
12


Location II
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
4
1
3
5


Location II
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_i
(Bars)
7
9
6
8


Location II
θ
.7
.6
.5
.4
.3
.2
.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
P_j
(Bars)
10
11